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RESEARCH MEMORANDUM

ALTITUDE ACCELERATION INVESTIGATION OF THE RA-14 AVON TURBOJET ENGINE

By Robert E. Russey

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
WASHINGTON

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RESEARCH MEMORANDUM

ALTITUDE ACCELERATION INVESTIGATION OF THE RA-14 AVON TURBOJET ENGINE

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SUMMARY

An investigation of the performance of the RA-14 Avon turbojet engine was made in an altitude test chamber at the NACA Lewis laboratory. As a part of this investigation, the acceleration characteristics of the engine, using the standard engine fuel-control system, were obtained for conditions simulating flight at altitudes of 35,000 and 50,000 feet with a flight Mach number of 0.4.

Rapid and wave-off type accelerations were made at each flight condition. A rapid acceleration is made by moving the throttle from initial to rated speed position in 1 second or less. The wave-off type acceleration consists of a rapid deceleration from rated to idle speed, followed by a rapid acceleration to rated speed when the engine nears idle speed.

At an altitude of 35,000 feet, rapid acceleration from idle to rated speed was possible, although one attempt resulted in a surge of short duration. Surge was encountered during the acceleration part of a wave-off type acceleration, but the engine accelerated through it. Acceleration times for the rapid and the wave-off type accelerations were approximately 8 and 10 seconds, respectively.

At an altitude of 50,000 feet, a successful rapid acceleration was made from a starting speed of 7450 rpm. Acceleration attempts from initial speeds of idle, 6150, and 6430 rpm resulted in surge and blowout. Acceleration through surge may have been prevented by limitations imposed by the engine fuel control. Acceleration was not possible during the wave-off type acceleration at this flight condition.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, the altitude performance of the RA-14 Avon turbojet engine was

investigated in an altitude test chamber at the NACA Lewis laboratory. As a part of this investigation, the acceleration characteristics of the engine were determined for conditions simulating flight at altitudes of 35,000 and 50,000 feet with a flight Mach number of 0.4. The standard engine fuel-control system was used to obtain the acceleration data. Information concerning the altitude performance of the standard engine is given in reference 1.

Rapid and wave-off type accelerations were investigated at each flight condition. The rapid acceleration is normally started with the engine at idle speed. The wave-off type acceleration consists of a rapid deceleration from rated to idle speed, followed by a rapid acceleration to rated speed when the engine nears idle speed. These acceleration data were obtained in the form of oscillograph traces, and are presented in this report as plotted time histories of the several performance parameters.

APPARATUS

The RA-14 Avon turbojet engine has a 15-stage axial-flow compressor, a cannular-type combustor with eight tubular liners, and a two-stage turbine. At rated conditions, the engine speed is 7850 rpm and the turbine discharge temperature is 1148° F. At sea-level static conditions, rated thrust is 9500 pounds and rated air flow is 152 pounds per second.

The compressor has variable inlet guide vanes and a two-position acceleration bleed valve which controls air bleed from the seventh stage. The guide-vane varies 35° from open to closed, and, at the fully open position (-10°), the incidence angle is -10° at the mean blade height. Inlet-guide-vane position is a linear function of corrected engine speed between 6100 and 7200 rpm. At corrected speeds below 6100 rpm, the inlet guide vanes are fully closed (+25°), whereas at corrected speeds above 7200 rpm, the inlet guide vanes are fully open (-10°). The acceleration bleed valve at the seventh stage of the compressor is fully open at corrected speeds below 6200 rpm and fully closed at corrected speeds above 6200 rpm.

The engine fuel-control system varies fuel flow according to throttle valve position, engine inlet total pressure, compressor discharge total pressure, and rated mechanical speed. The purpose of the acceleration control is to prevent the occurrence of compressor surge or overspeeding of the engine by limiting excess fuel flow to a safe margin above the steady-state operating line. A typical fuel-flow schedule for both steady-state operation and acceleration is shown in figure 1. The steady-state operating line (curve A-D, fig. 1) is controlled by throttle valve position and engine-inlet total pressure. The acceleration fuel-control unit schedules the excess fuel flow required for acceleration according to two separate functions of compressor-discharge total

pressure in order to avoid the knee in the stall line. Fuel flow along the first segment of the acceleration path (curve A-B, fig. 1) is a function of compressor-discharge total pressure up to a compressor pressure ratio of approximately 5, when fuel flow along the second segment of the acceleration path (curve B-C, fig. 1) becomes a different function of compressor-discharge total pressure. Fuel flow along the third segment of the acceleration path (curve C-D, fig. 1) is controlled by the top-speed governor.

Fuel conforming to MIL-F-5624A grade JP-4 specifications was used throughout the investigation. The lower heating value of the fuel is 18,700 Btu per pound and the hydrogen-carbon ratio is 0.169.

Installation

The engine was installed in an altitude test chamber (fig. 2), where inlet temperatures and pressures and ambient exhaust pressures could be regulated to simulate altitude flight conditions. Engine inlet pressure during the transients was maintained constant at the desired ram pressure by means of an automatic bulkhead valve, which acted to regulate the amount of air bypassed from the inlet compartment to the engine compartment.

Although no provisions were made to hold altitude static pressure constant during the transients, this pressure remained reasonably constant until after the exhaust nozzle choked during acceleration.

Instrumentation

Instrumentation station locations throughout the engine are shown in figure 3, and a list of transient and steady-state instrumentation is presented in table I. Transient data were photographed with a multiple-channel oscillograph. The accelerations were monitored with a pen-type multiple-channel oscillograph.

Although a compensating thermocouple, one which uses an electronic network to compensate for thermocouple lag, was used at station 9 to measure transient exhaust-gas temperatures, the degree of compensation obtained was believed somewhat inadequate.

PROCEDURE

Acceleration data were obtained for conditions simulating a flight Mach number of 0.4, at altitudes of 35,000 and 50,000 feet. At each flight condition, two types of acceleration were investigated.

The first type consisted of a rapid acceleration from idle to rated speed. The second type was a wave-off acceleration, which consisted of a rapid deceleration from rated to idle speed, followed by a rapid acceleration to rated speed when the engine neared idle speed. In general, approximately 3 minutes were allowed for the engine to reach equilibrium conditions prior to an acceleration attempt. In the case of the wave-off type acceleration, the engine was operated at rated speed for a similar period of time.

At the desired flight condition, with the throttle in either the idle position (prior to rapid acceleration from idle speed) or the rated speed position (prior to a wave-off type acceleration), steady-state data were taken and the deflections recorded on the oscillograph. The throttle was then moved rapidly and the transient variation of the engine parameters was recorded. Steady-state data were taken at frequent intervals following the transients in order to establish the necessary trace calibrations.

At the 35,000-foot-altitude flight condition, attempts were also made to rapidly accelerate the engine from nominal initial rotor speeds of 7450 and 7650 rpm; whereas at 50,000 feet accelerations were attempted from nominal initial rotor speeds of 6150, 6430, and 7450 rpm as well as from idle speed.

RESULTS AND DISCUSSION

Although the data were recorded on a multiple-channel oscillograph, the records obtained were too large to be completely reproduced in this report. The parameters are, therefore, presented in the form of plotted time histories obtained from the oscillograph traces, to describe the behavior of the variables during the accelerations investigated. Short segments of the oscillograph recordings are presented, however, in order to more completely describe the behavior of the engine parameters when surge was encountered.

The oscillograph traces are labeled on one end with identification symbols, steady-state values, and an arrow to denote direction of increase. The opposite end is labeled with identification symbols, values for each trace at some particular time during the transient, calibration constants for each trace, and an inch scale. Absolute levels of large- and small-slot fuel pressures were not obtained.

At an altitude of 35,000 feet it was possible to accelerate the engine from any initial speed to rated speed, regardless of the type of acceleration attempted. One cycle of surge occurred during a rapid acceleration from idle speed, and an eight-cycle surge occurred during each of the wave-off type accelerations. The engine was able to accelerate through these surges at this altitude.

Figures 4 and 5 (table II) show engine parameters during a rapid acceleration from idle to rated speed at 35,000 feet. It should be noted that one acceleration attempt was surge free (fig. 4), while the other went through one cycle of surge (fig. 5). Peak exhaust-gas temperature during the surge was relatively low because of the reduction in fuel flow which occurred when compressor discharge total pressure decreased. Time to accelerate to rated speed was approximately 8 seconds for the surge-free attempt, while the acceleration during which surge occurred took approximately 8.4 seconds to reach rated speed. A difference in the mode of operation is probably responsible for the difference in acceleration characteristics shown in these two attempts. Prior to the acceleration shown in figure 4, the engine was operated at the idle condition for approximately 3 minutes, as was previously mentioned in the PROCEDURE section. It is believed that the engine was operated at the idle condition for a shorter period of time prior to the acceleration shown in figure 5.

Figures 6 and 7 show acceleration attempts at 35,000 feet from speeds of 7450 and 7650 rpm, respectively. Time for the first attempt to reach rated speed was approximately 3 seconds, whereas the second attempt reached rated speed in approximately 2 seconds.

Figure 8 shows a wave-off type acceleration at an altitude of 35,000 feet, during which the engine surged but continued to accelerate. The engine fuel flow, which was regulated automatically by the control, followed compressor-outlet total pressure rather closely in all the acceleration attempts, which accounts for the fact that engine temperature stayed within reasonable limits. Maximum engine speed was controlled by the governor without any overshoot.

The trace of compressor-outlet total pressure P_3 was inadvertently lost from record during the wave-off type accelerations. It was possible, however, to obtain values for this parameter from another type of recording oscillograph which was used to monitor the acceleration attempts. The values of P_3 obtained from the monitor compare favorably with those from the record, wherever comparisons were possible. These values of P_3 are presented in figure 8(e).

The acceleration data show that the inlet-guide-vane control system failed to produce a consistent guide-vane schedule during the acceleration attempts. Figure 9(a) compares the transient guide-vane schedules obtained during four acceleration attempts with the preferred or production average schedule.

Possibly the variation in inlet-guide-vane schedule observed in figure 9(a) may have been caused by ambient pressures and temperatures in the engine compartment of the test chamber being different from the

pressures and temperatures experienced by the engine in actual flight. This variation may possibly have been due to a malfunction of the guide-vane control system, which gave an erroneous engine-inlet temperature bias. In addition, variations in the time allowed for the engine to reach equilibrium conditions might influence either of the above arguments.

A comparison of the guide-vane schedules for the deceleration and acceleration portions of the wave-off type acceleration (fig. 8) indicated that there was some hysteresis present in the guide-vane control system. This hysteresis loop is indicated by curve A-B-C-D-E-A in figure 9(a).

Figure 9(b) compares the compressor-pressure-ratio acceleration paths obtained for two rapid accelerations (figs. 4 and 5) and two wave-off type accelerations, only one of which is presented in this report (fig. 8). It should be noted that the time allowed for the engine to reach equilibrium conditions prior to acceleration from idle speed was different for the two rapid accelerations, as was mentioned previously. Equilibrium times for the two wave-off type accelerations were comparable. The surge points for the wave-off type accelerations were obtained from peaks of compressor pressure ratio as the engine accelerated through surge to rated speed.

Steady-state operating lines from unpublished data are also presented in figure 9(b) to indicate the effect of varying guide-vane schedule. These operating lines indicate steady-state compressor pressure ratios that would result from the guide-vane schedule shown in figure 9(a). The difference in compressor pressure ratio obtained for the rapid and wave-off type accelerations must be considered partly due to the shifting of the inlet-guide-vane schedule.

Figure 9(c) shows the corrected fuel-flow schedule followed by the engine fuel control during the four accelerations and includes a steady-state operating line for the production average or preferred guide-vane schedule. The fuel flows at surge for the wave-off type accelerations were obtained at peaks of compressor pressure ratio as the engine accelerated through surge to rated speed.

At an altitude of 50,000 feet it was not possible to accelerate the engine to rated speed from initial speeds of 6430 rpm and below. All acceleration attempts from initial speeds in this range were terminated by surge through which the engine would not accelerate. In some cases, surge was followed by blowout. Acceleration through surge may have been prevented by limitations imposed by the engine fuel control. One successful rapid acceleration was made from an initial speed of 7450 rpm.

Figures 10 to 12 show three attempts to accelerate the engine from idle to rated speed at the 50,000-foot-altitude flight condition, which were all terminated by the occurrence of surge. Engine blowout followed surge during the attempt shown in figure 12. Except for a successful rapid acceleration attempt (fig. 13) from an initial speed of 7450 rpm, where the time required to reach a top speed of 7740 rpm was approximately 6 seconds, all other acceleration attempts at the 50,000-foot-altitude flight condition were terminated by the occurrence of surge. These attempts are shown in figures 14 to 17, for initial speeds of 6150 rpm (fig. 14), 6430 rpm (figs. 15 and 16), and for a wave-off type acceleration (fig. 17). Engine blowout occurred during the attempts shown in figures 14 and 16.

CONCLUDING REMARKS

An investigation of the acceleration characteristics of the RA-14 Avon turbojet engine was made in an altitude test chamber at the NACA Lewis laboratory. This investigation was made at conditions simulating a flight Mach number of 0.4 for altitudes of 35,000 and 50,000 feet. The standard engine fuel-control system was used.

Rapid and wave-off type accelerations were made at each flight condition. A rapid acceleration is made by moving the throttle from the initial speed position to rated speed position in 1 second or less. The wave-off type acceleration consists of a rapid deceleration from rated to idle speed, followed by a rapid acceleration to rated speed when engine nears idle speed.

At 35,000 feet, the engine accelerated from idle to rated speed in 8 seconds, while time from idle to rated speed for a wave-off type acceleration was 10 seconds. One cycle of surge occurred during a rapid acceleration from idle speed, while the engine accelerated through eight cycles of surge during the wave-off type accelerations.

At the 50,000-foot altitude, neither wave-off type nor rapid accelerations from initial speeds of idle, 6150, and 6430 rpm were possible because of the occurrence of surge and blowout. Acceleration through surge may have been prevented by limitations imposed by the engine fuel control. A rapid acceleration from 7450 rpm to a top speed of 7740 rpm was made in approximately 6 seconds.

Throughout the investigation, the engine fuel control system displayed a latent ability to lessen the effects of compressor surge by decreasing excess fuel flow as compressor discharge total pressure decreased, thereby avoiding excessive exhaust-gas temperatures.

Lewis Flight Propulsion Laboratory
National Advisory Committee for Aeronautics
Cleveland, Ohio, March 13, 1956

APPENDIX - SYMBOLS

The following symbols are used in this report:

N engine speed, rpm

P total pressure, lb/sq ft abs

p static pressure, lb/sq ft abs

S_l large slot, main fuel pressure, lb/sq in.

S_s small slot, pilot fuel pressure, lb/sq in.

T total temperature, $^{\circ}R$

W_f fuel flow, lb/hr

θ ratio of absolute total temperature to absolute static temperature of standard NACA atmosphere at sea level

δ ratio of absolute total pressure to absolute static pressure of standard NACA atmosphere at sea level

Subscripts:

0 free stream

2 compressor inlet

3 compressor outlet

9 exhaust-nozzle inlet

REFERENCE

1. Sivo, Joseph N., and Jones, William L.: Preliminary Altitude Performance Data for the RA-14 Avon Turbojet Engine. NACA RM E55K07a, 1955.

TABLE I. - INSTRUMENTATION

Parameter	Engine station	Steady-state instrumentation	Transient instrumentation
Engine throttle	--	Manual	Limit switches at idle and full throttle positions
Engine fuel flow	--	Calibrated rotometer	AC output of a flow meter rectified with voltage proportional to fuel flow
Compressor inlet total pressure	2	Average of 18 total pressure probes	Aneroid-type pressure sensor, with strain-gage element
Compressor outlet total pressure	3	Average of 20 total pressure probes	Aneroid-type pressure sensor, with strain-gage element
Altitude static pressure	10	Average of four lip static-pressure probes at exhaust-nozzle exit	Aneroid-type pressure sensor, with strain-gage element
Exhaust-nozzle inlet total pressure	9	Average of 16 total pressure probes at exhaust-nozzle inlet	Aneroid-type pressure sensor, with strain-gage element
Exhaust-nozzle inlet total temperature	9	Average of 22 thermocouples	Single thermocouple with electronic network to compensate for thermocouple lag
Inlet-guide-vane position	--	Potentiometer connected to master guide vane	Same as steady state
Interstage bleed position	--	Two total and one static pressure inlet bleed duct	Bourdon type pressure sensor completing electric circuit
Engine speed	--	Engine tachometer generator and electronic pulse counter	Engine tach-generator, AC rectified with voltage proportional to speed
Large slot, main fuel pressure	--	Bourdon gage	Twisted-tube pressure sensor with variable reluctance bridge
Small slot, pilot fuel pressure	--	Bourdon gage	Twisted-tube pressure sensor with variable reluctance bridge

TABLE II. - EXPERIMENTAL RESULTS

Figure	Altitude, ft	Flight Mach number	Range of acceleration attempts, rpm
4	35,000	0.4	Idle to rated
5			Idle to rated
6			7450 to rated
7			7650 to rated
8			Rated to idle to rated
9			Acceleration path comparisons
10	50,000		Idle to rated
11			Idle to rated
12			Idle to rated
13			7450 to rated[a]
14			6150 to rated
15			6430 to rated
16			6430 to rated
17			Rated to idle to rated

[a]Actual top speed 7740 rpm.

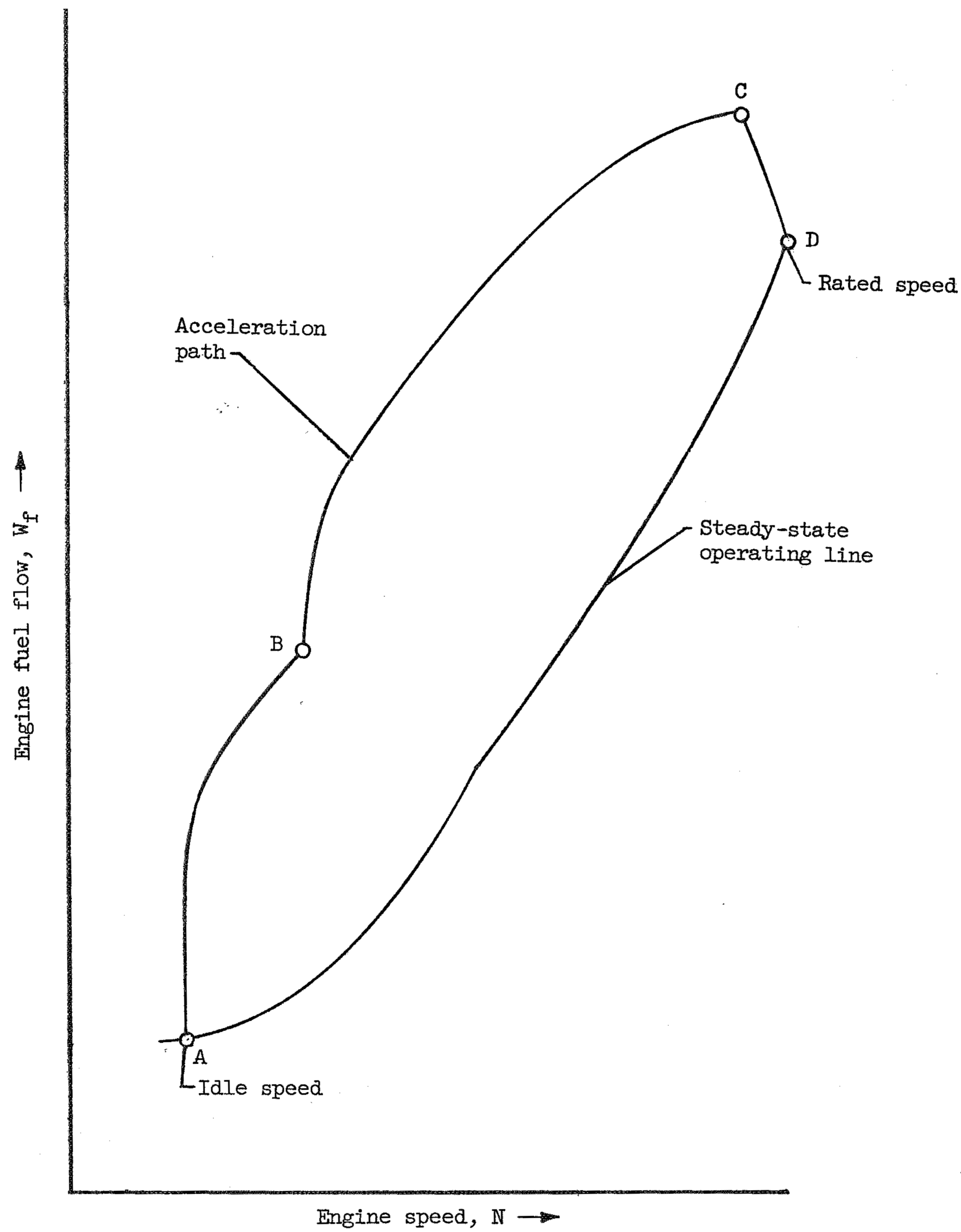

Figure 1. - Typical steady-state and acceleration fuel-flow schedule.

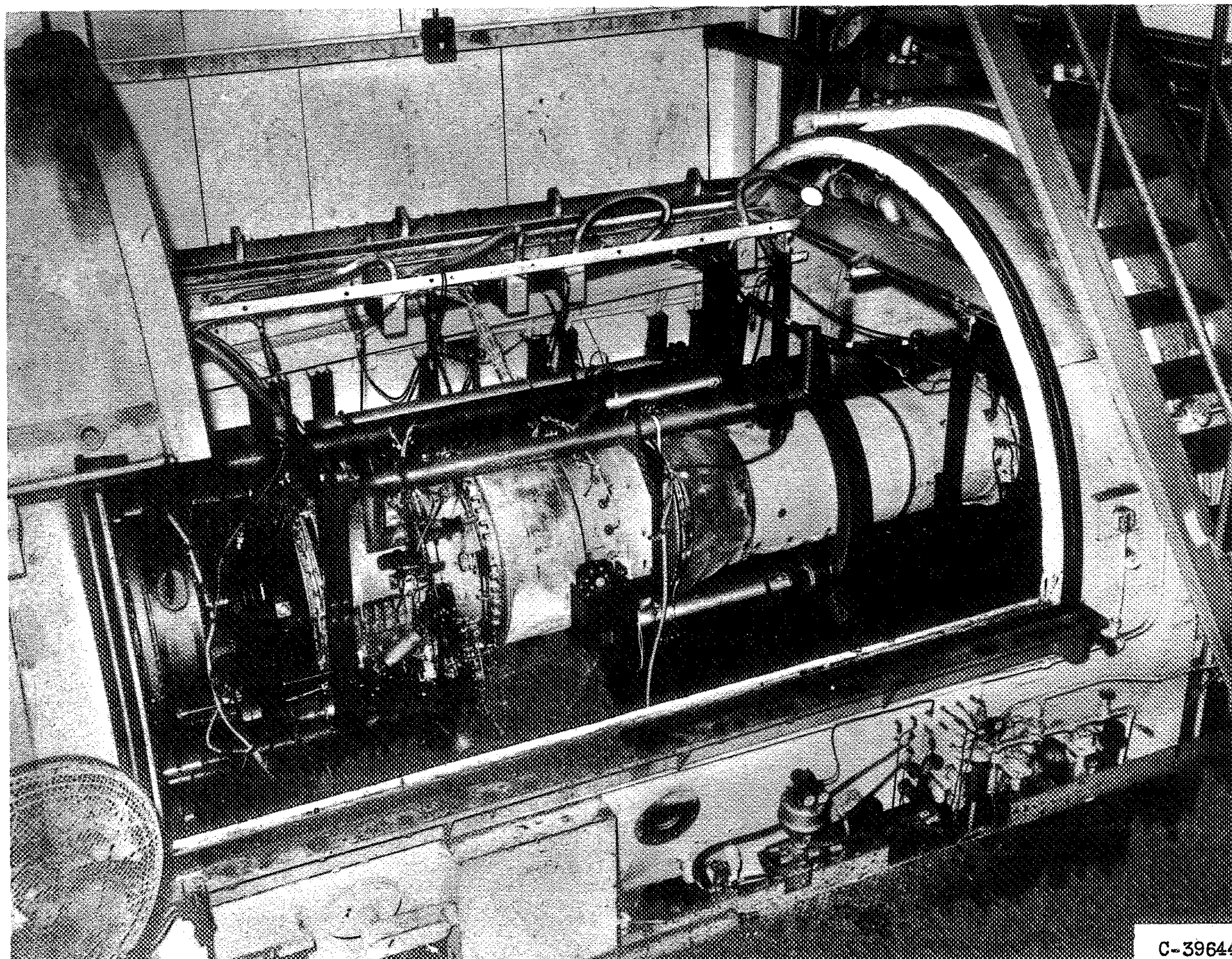

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Figure 2. - Avon RA-14 engine installed in altitude test chamber.

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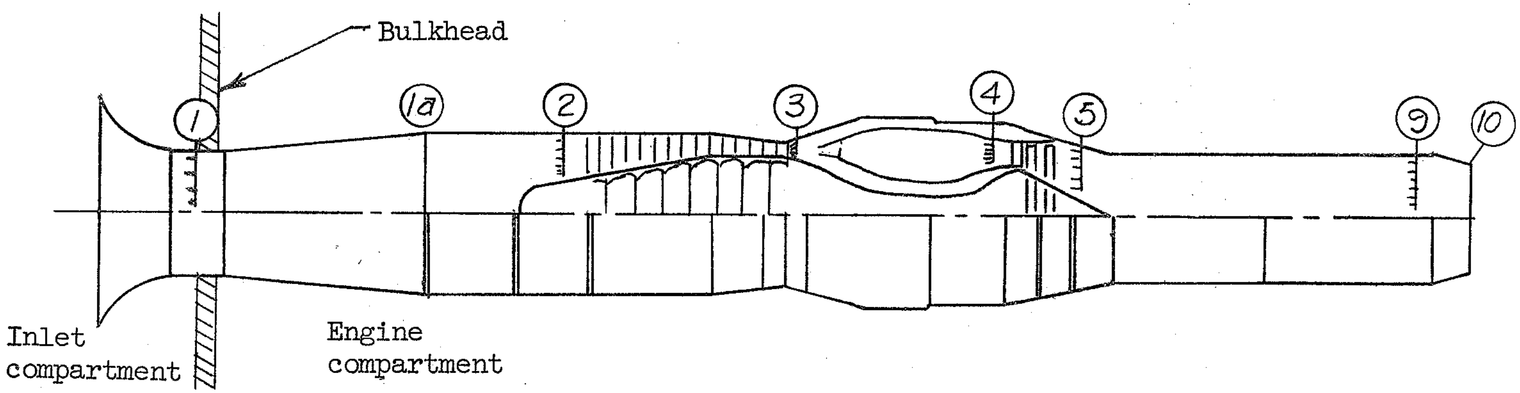

1	Venturi measuring station
1a	Engine inlet
2	Compressor inlet
3	Compressor discharge
4	Turbine inlet
5	Turbine discharge
9	Nozzle inlet
10	Exhaust nozzle

Figure 3. - Schematic diagram of engine showing instrumentation stations.

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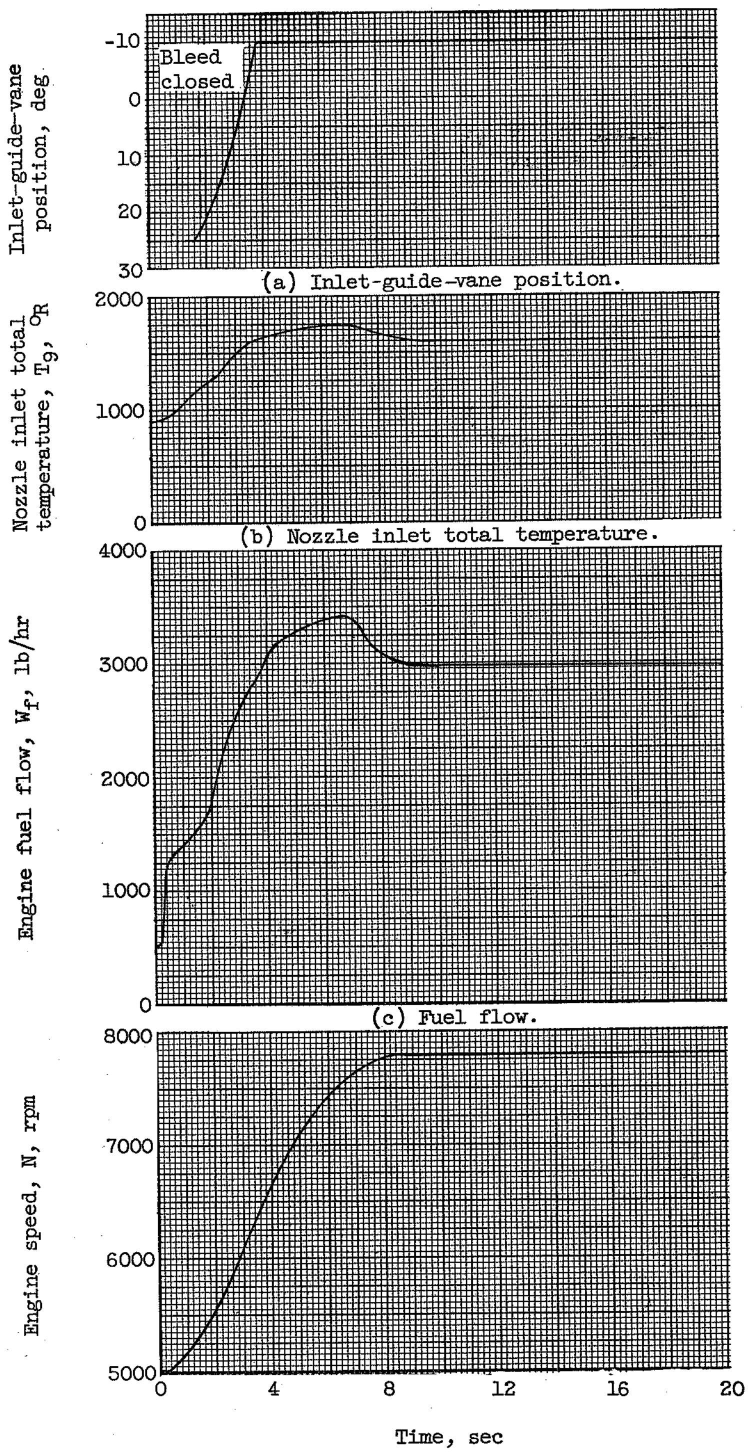
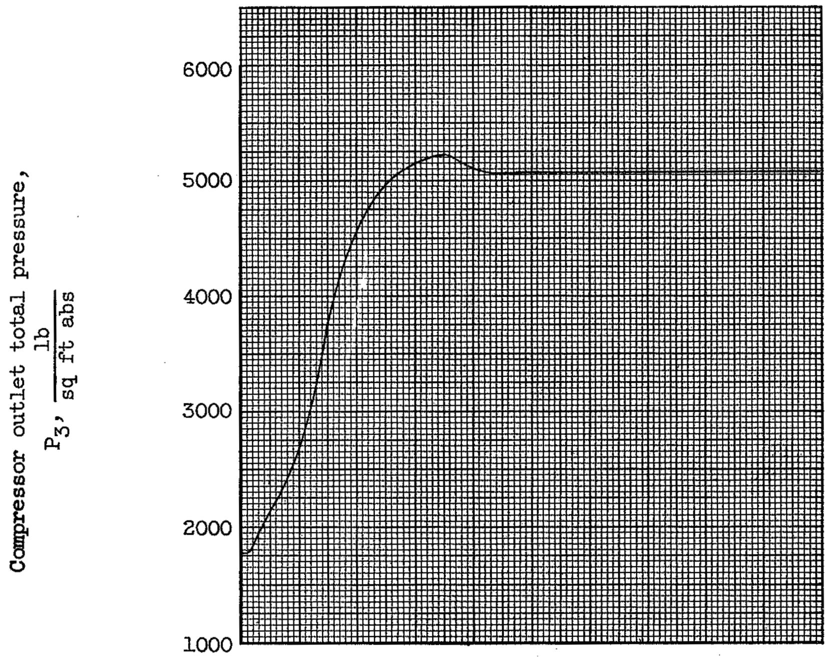
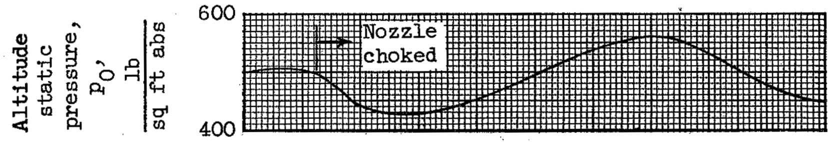


(d) Engine speed. Compressor inlet temperature, 410° R.

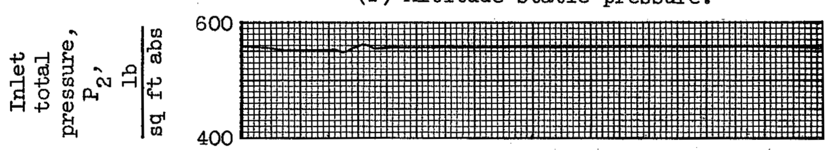
Figure 4. - Acceleration attempt from idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. No surge occurred.



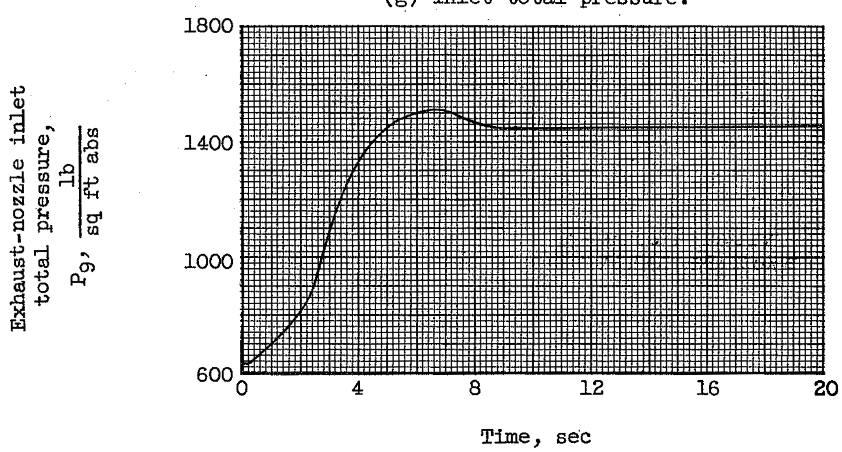
(e) Compressor outlet total pressure.



(f) Altitude static pressure.

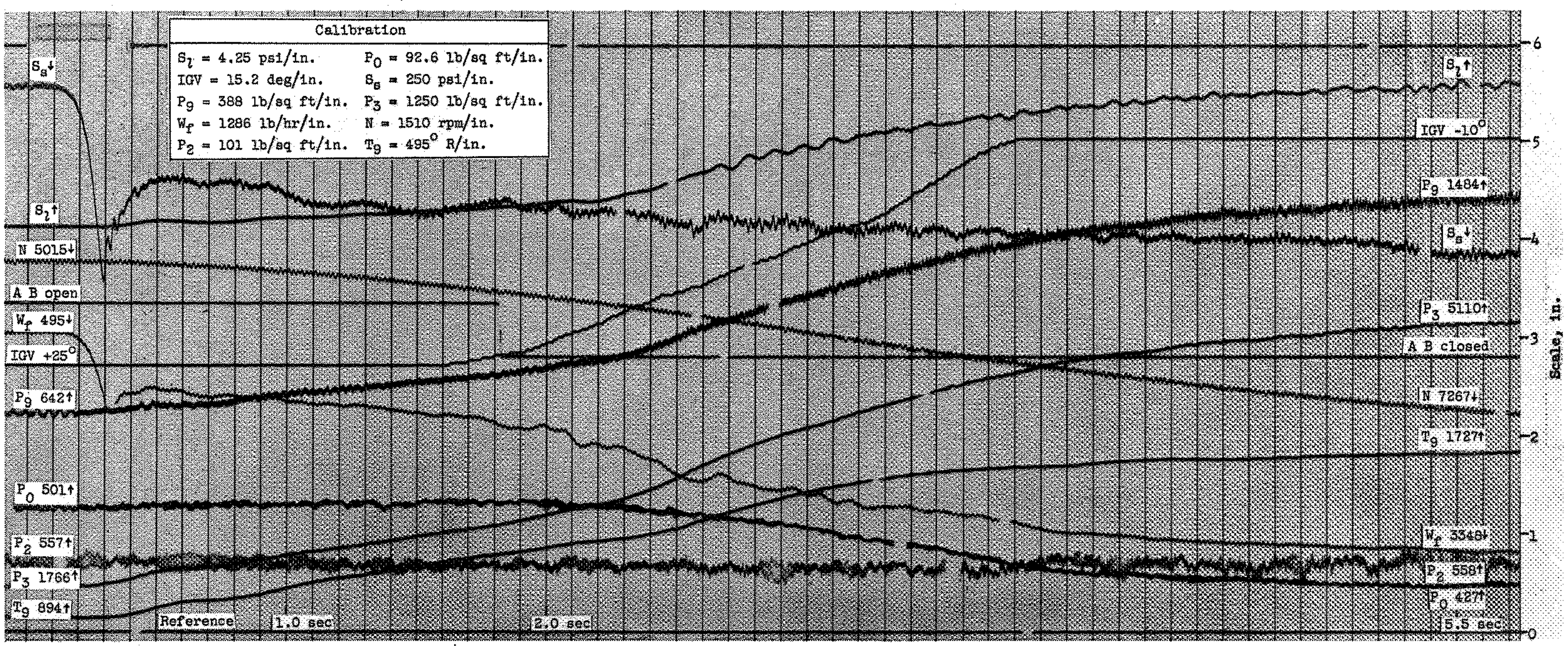


(g) Inlet total pressure.



(h) Exhaust-nozzle inlet total pressure.

Figure 4. - Continued. Acceleration attempt from idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. No surge occurred.



(i) Reproduction of oscillograph traces.

Figure 4. - Concluded. Acceleration attempt from idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. No surge occurred.

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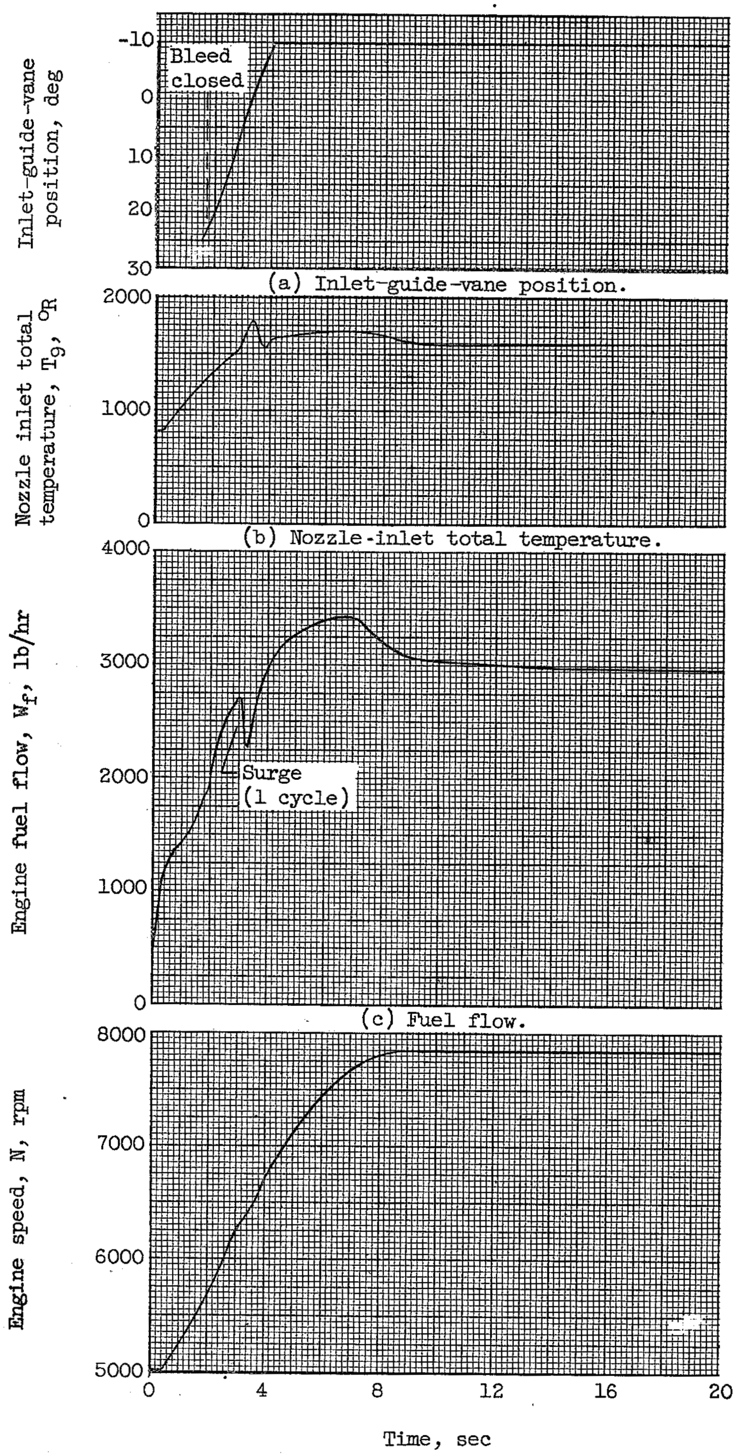
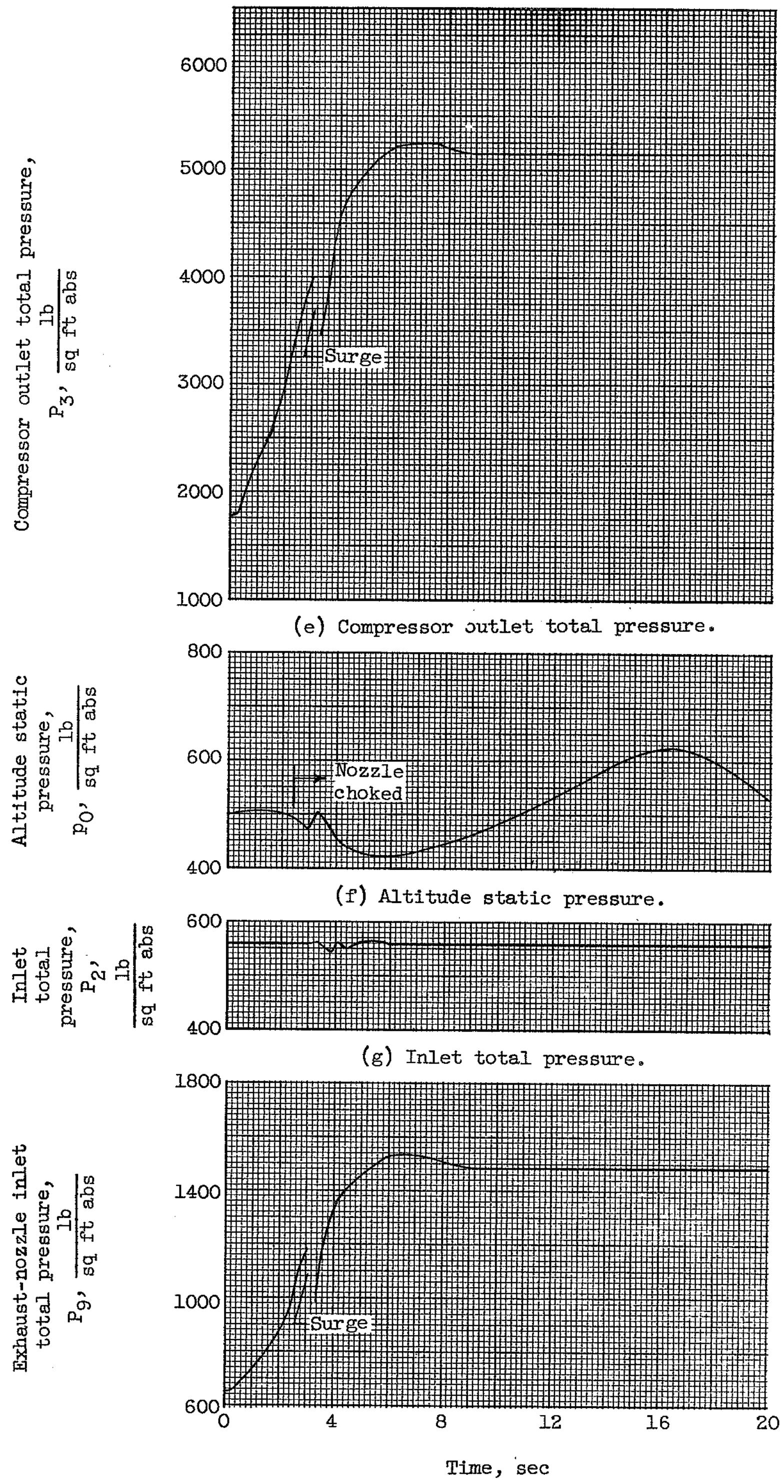


(d) Engine speed. Compressor inlet temperature, 409° R.

Figure 5. - Acceleration attempt from idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. Surge occurred.



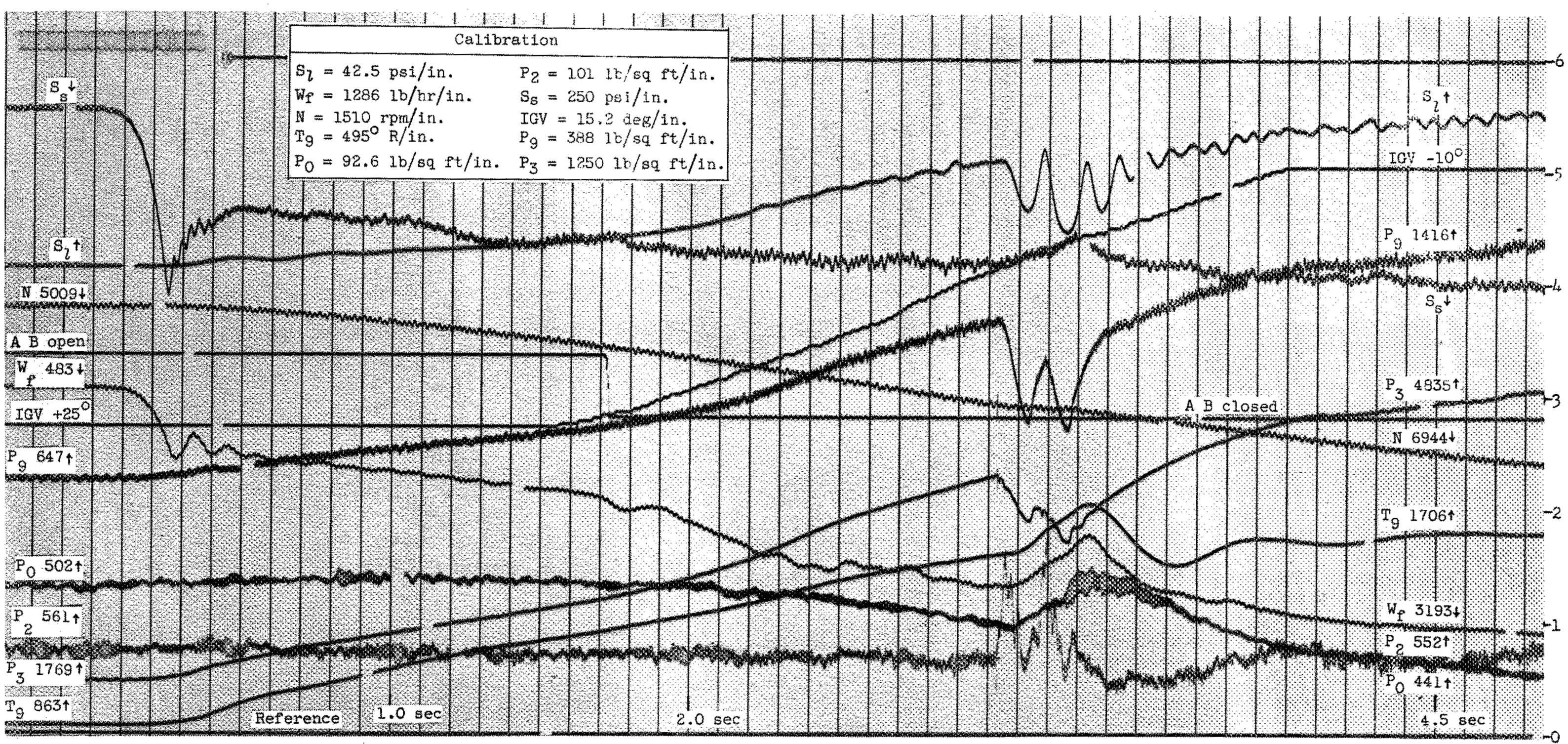
(e) Compressor outlet total pressure.

(f) Altitude static pressure.

(g) Inlet total pressure.

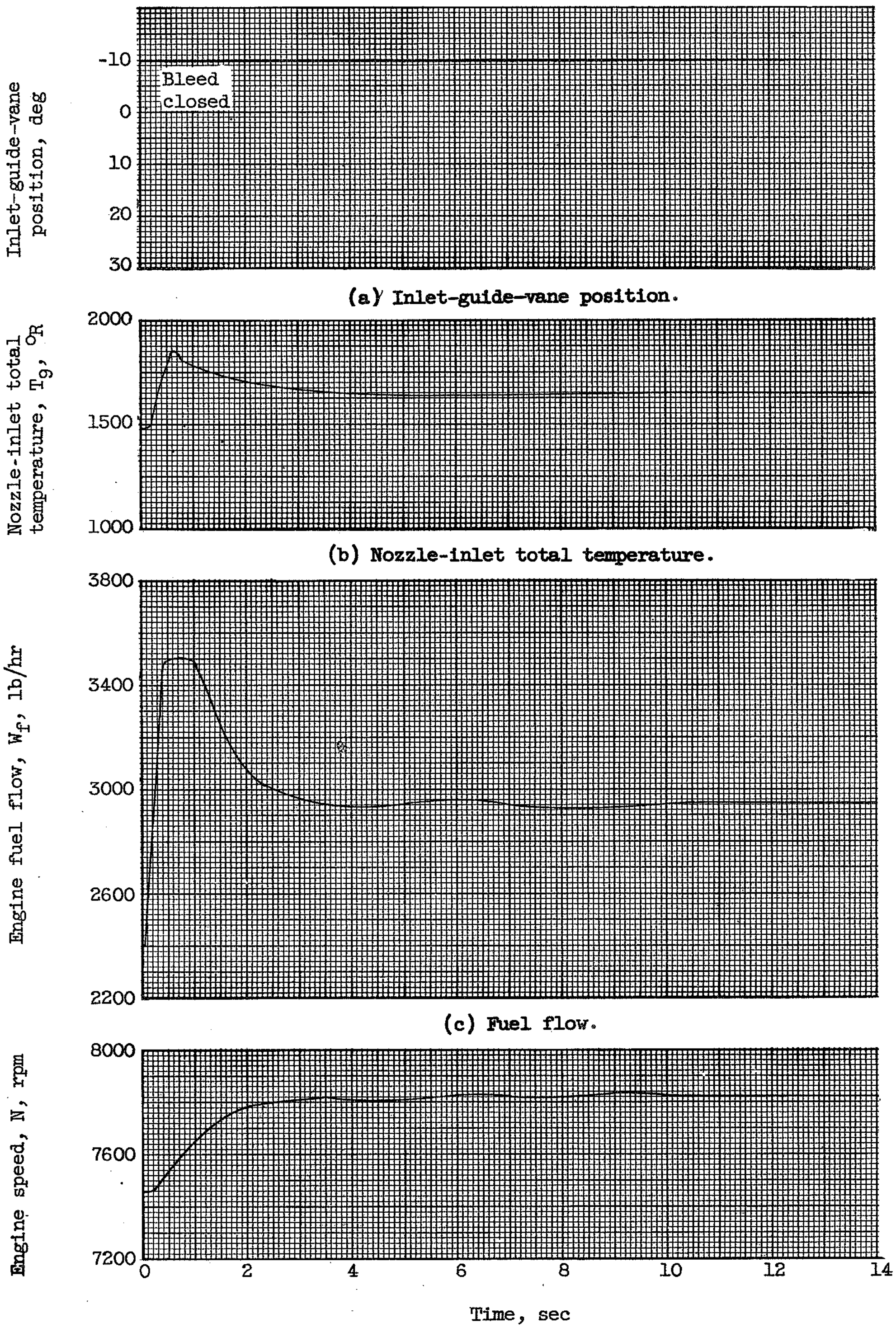
(h) Exhaust-nozzle inlet total pressure.

Figure 5. - Continued. Acceleration attempt from idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. Surge occurred.



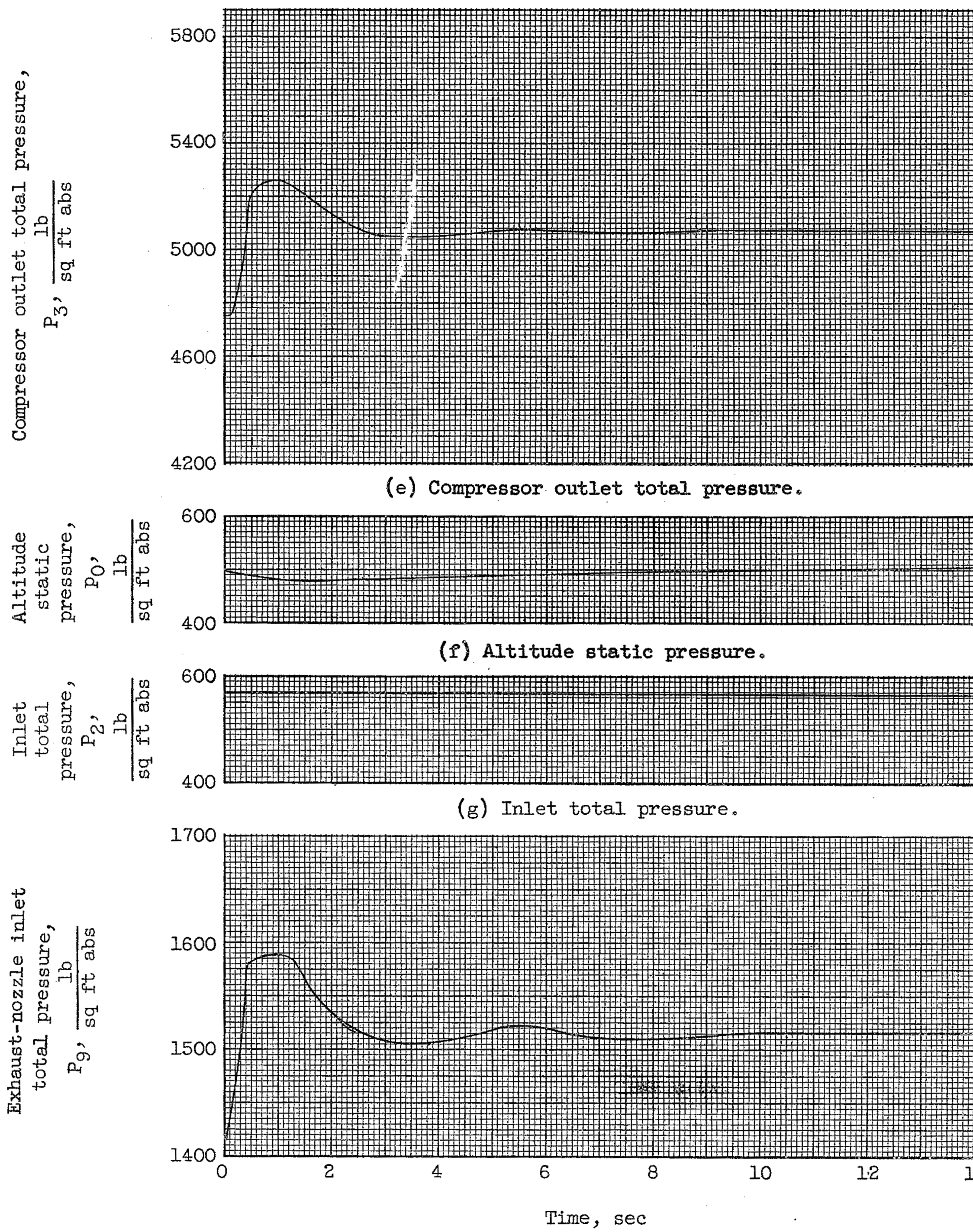
(i) Reproduction of oscillograph traces.

Figure 5. - Concluded. Acceleration attempt from idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. Surge occurred.



(d) Engine speed. Compressor inlet temperature, 411° R.

Figure 6. - Acceleration attempt from 7450 rpm to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4.



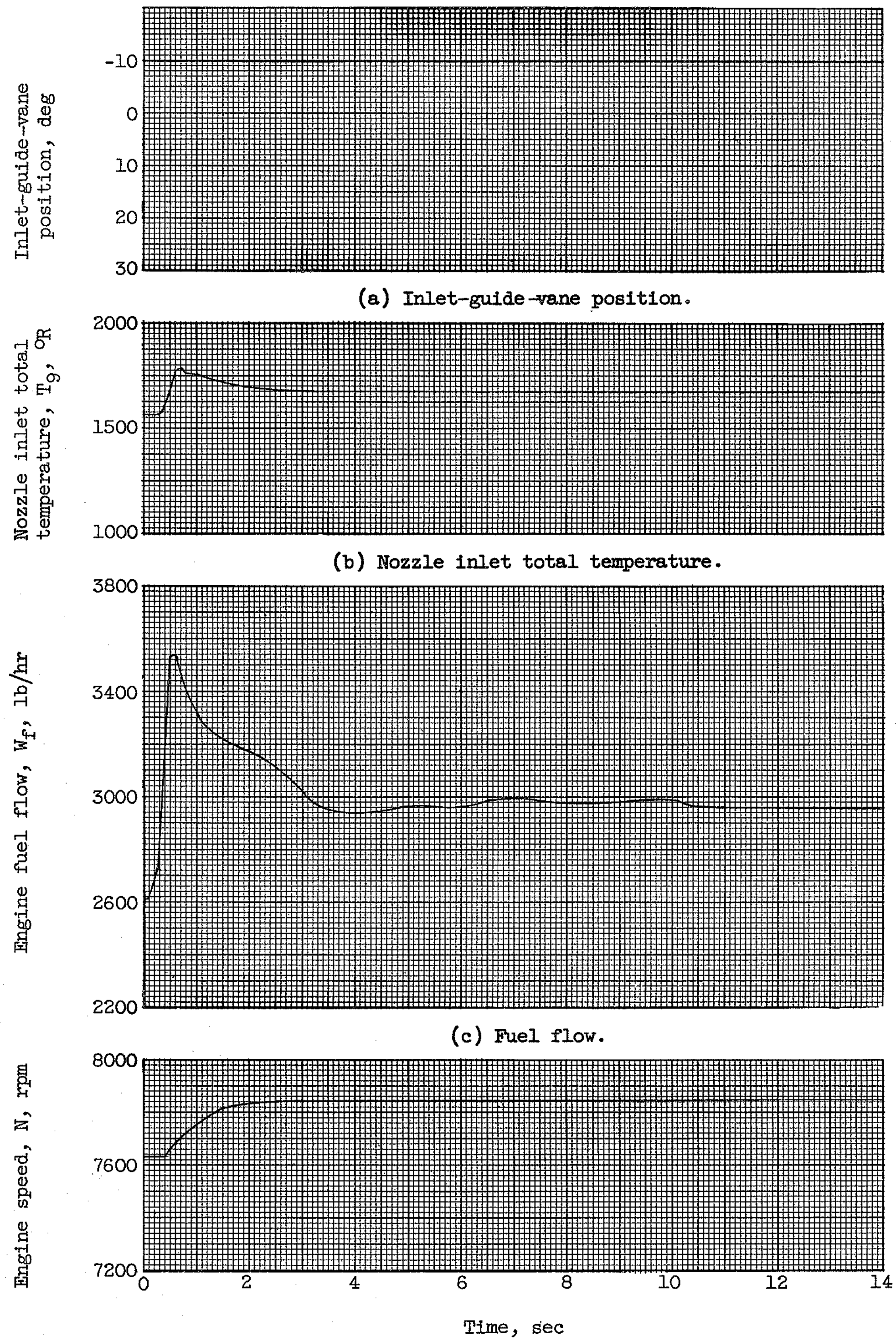
(e) Compressor outlet total pressure.

(f) Altitude static pressure.

(g) Inlet total pressure.

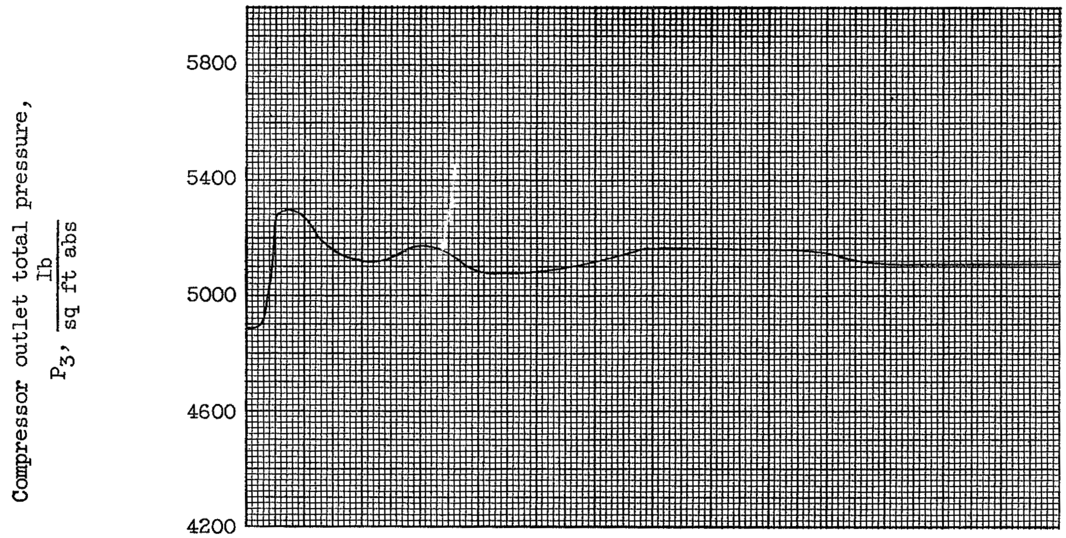
(h) Exhaust-nozzle inlet total pressure.

Figure 6. - Concluded. Acceleration attempt from 7450 rpm to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4.

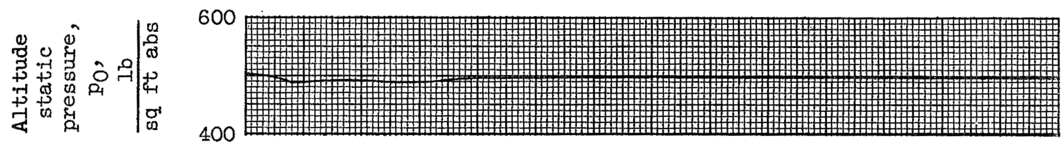


(d) Engine speed. Compressor inlet temperature, 408° R.

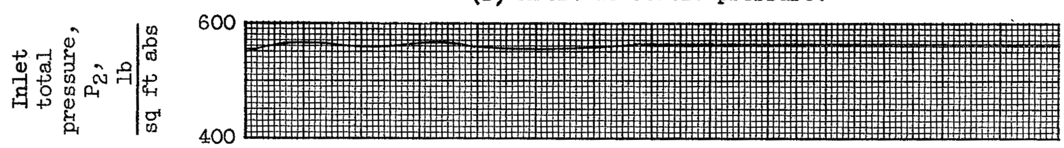
Figure 7. - Acceleration attempt from 7650 rpm to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4.



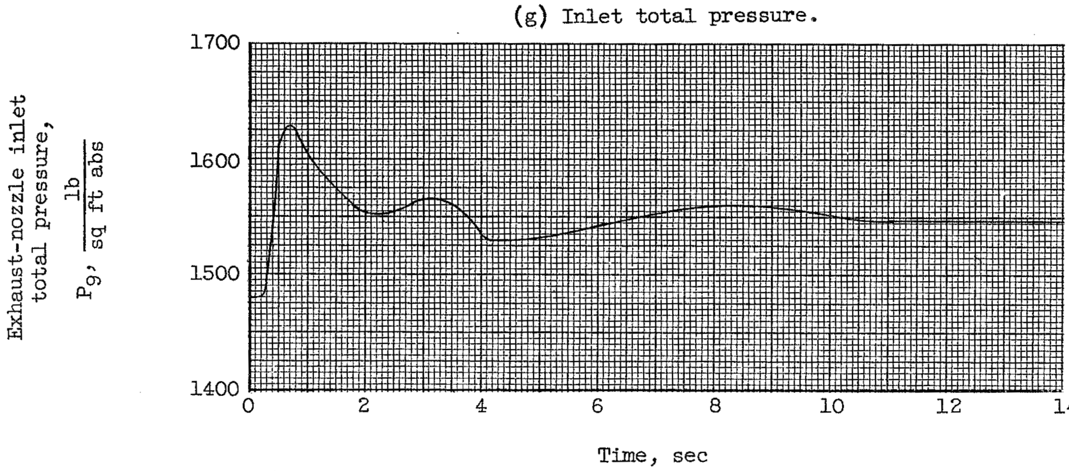
(e) Compressor-outlet total pressure.



(f) Altitude static pressure.

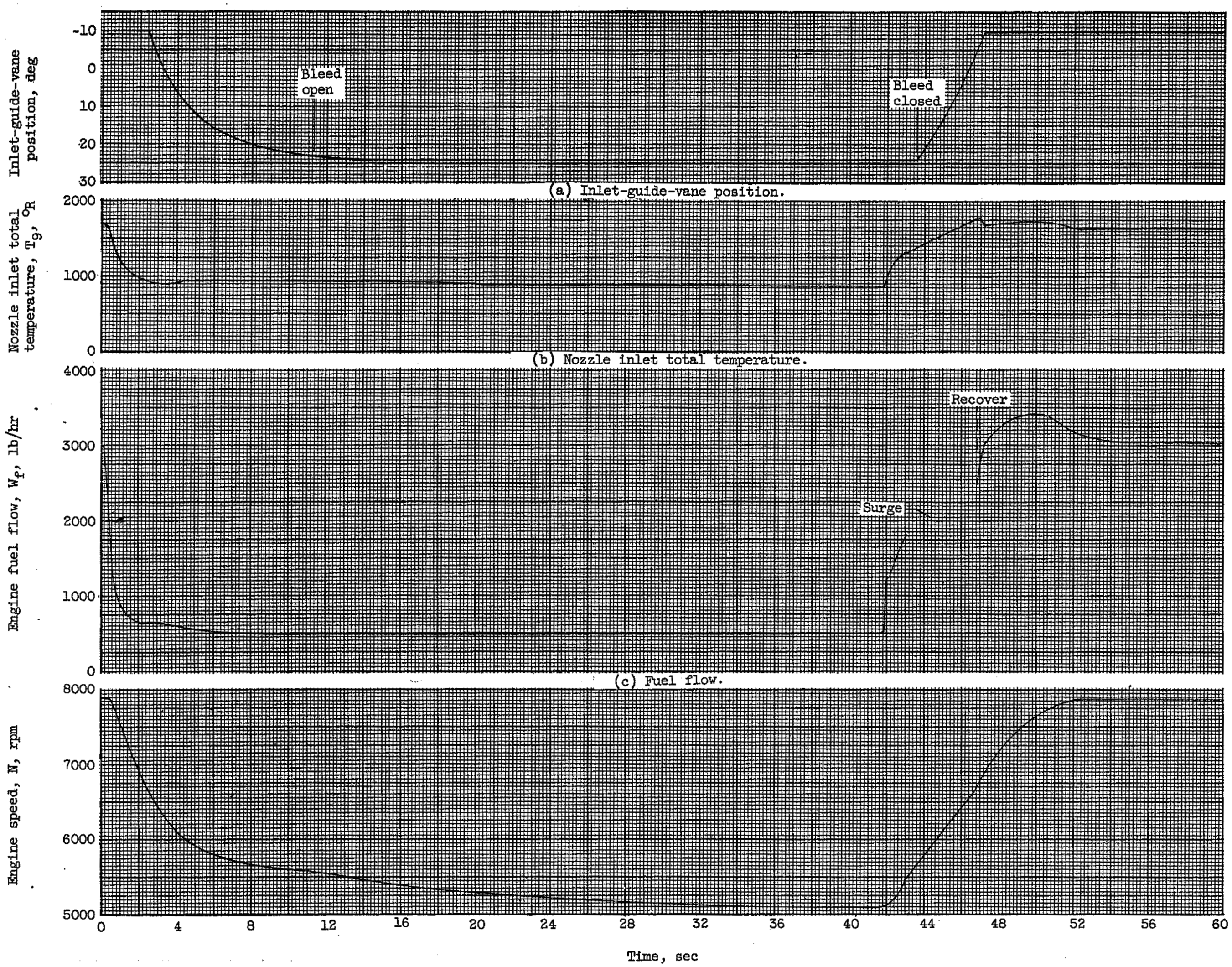


(g) Inlet total pressure.



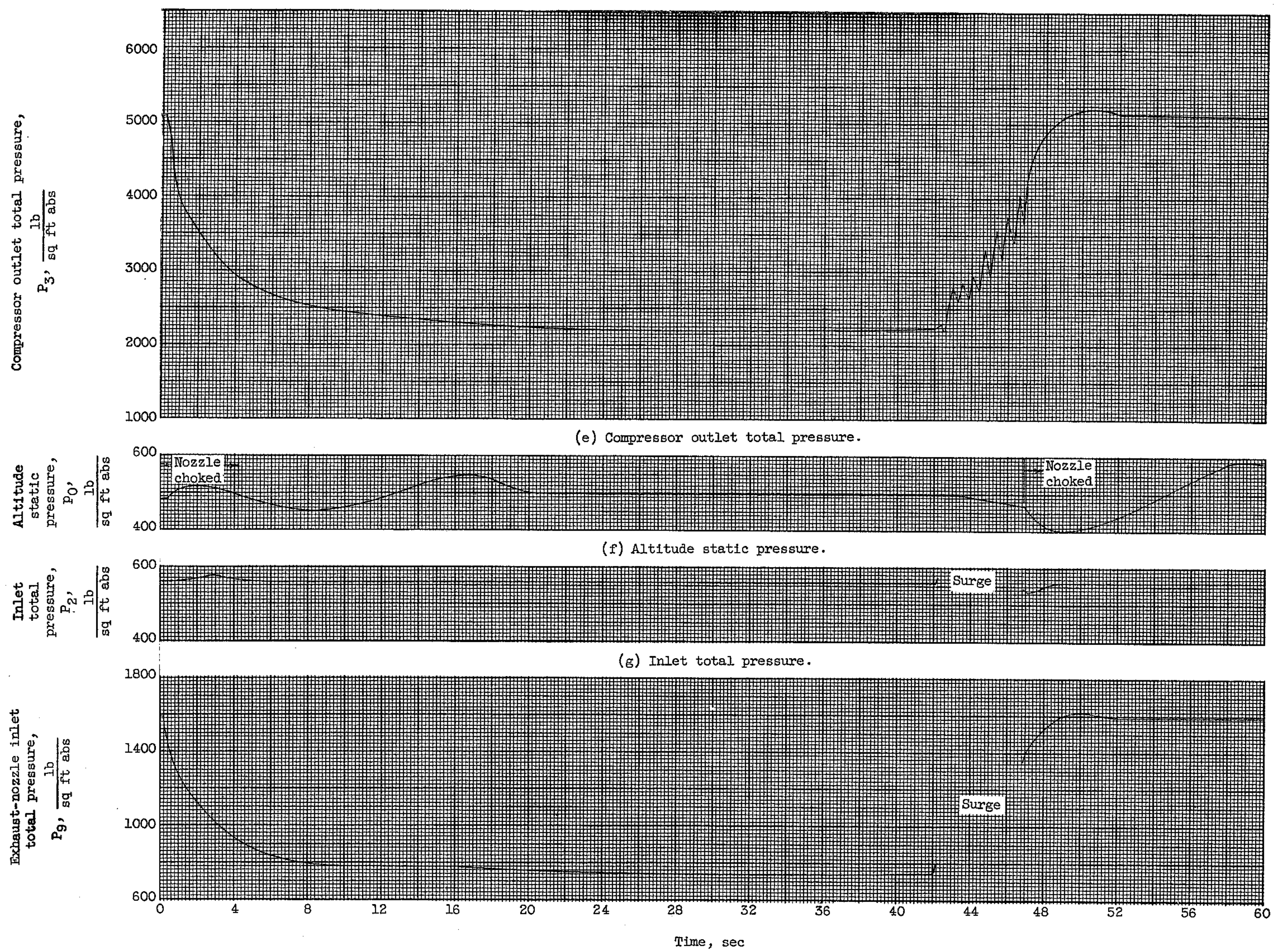
(h) Exhaust-nozzle inlet total pressure.

Figure 7. - Concluded. Acceleration attempt from 7650 rpm to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4.



(d) Engine speed. Compressor inlet temperature, 410° R.

Figure 8. - Wave-off type acceleration from rated speed to idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. Surge occurred during acceleration.



(e) Compressor outlet total pressure.

(f) Altitude static pressure.

(g) Inlet total pressure.

(h) Exhaust-nozzle inlet total pressure.

Figure 8. - Continued. Wave-off type acceleration from rated speed to idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. Surge occurred during acceleration.

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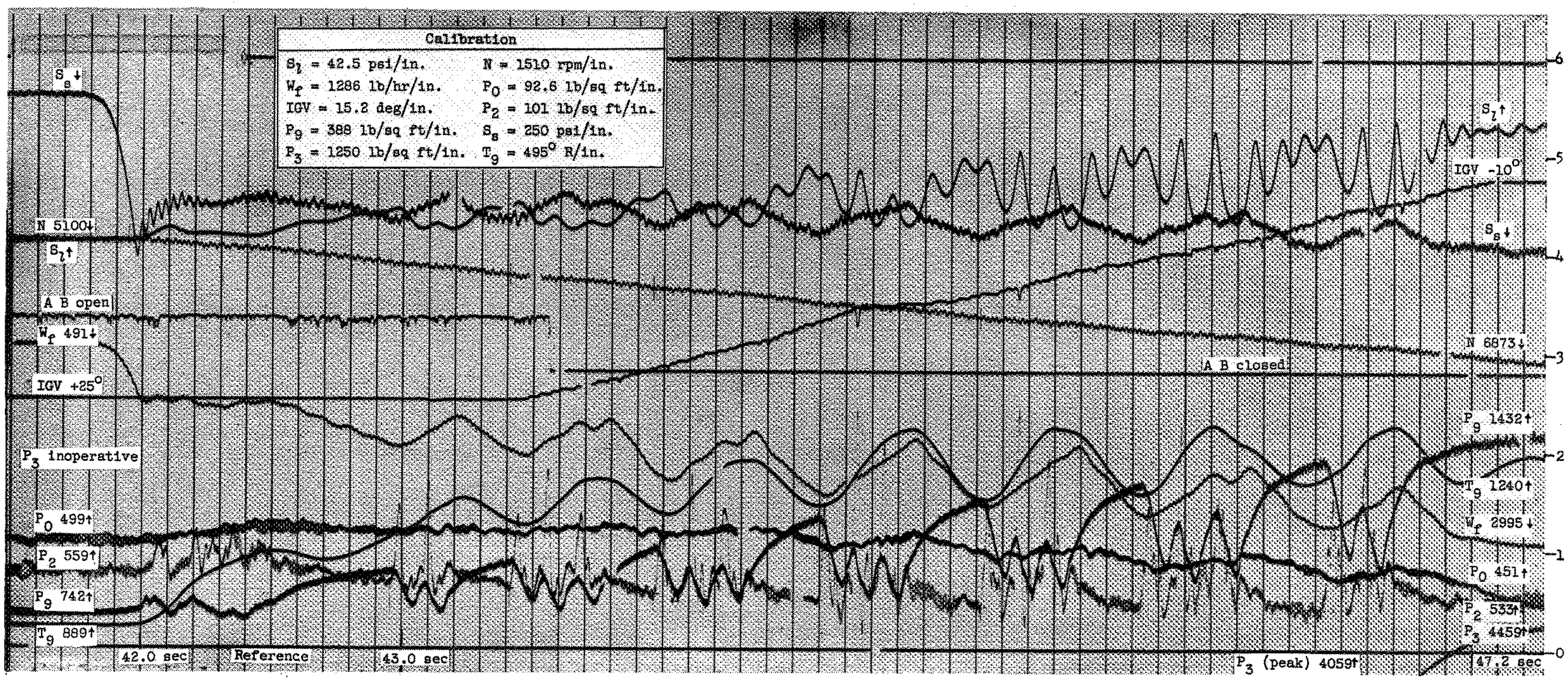

(i) Reproduction of oscillograph traces.

Figure 8. - Concluded. Wave-off type acceleration from rated speed to idle to rated speed. Altitude, 35,000 feet; flight Mach number, 0.4. Surge occurred during acceleration.

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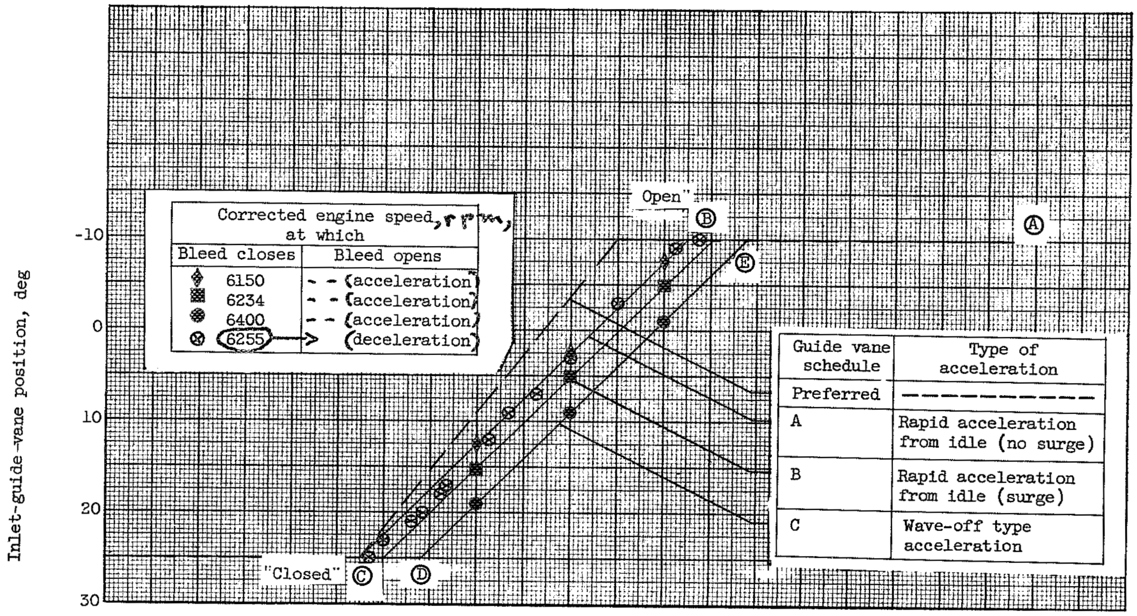
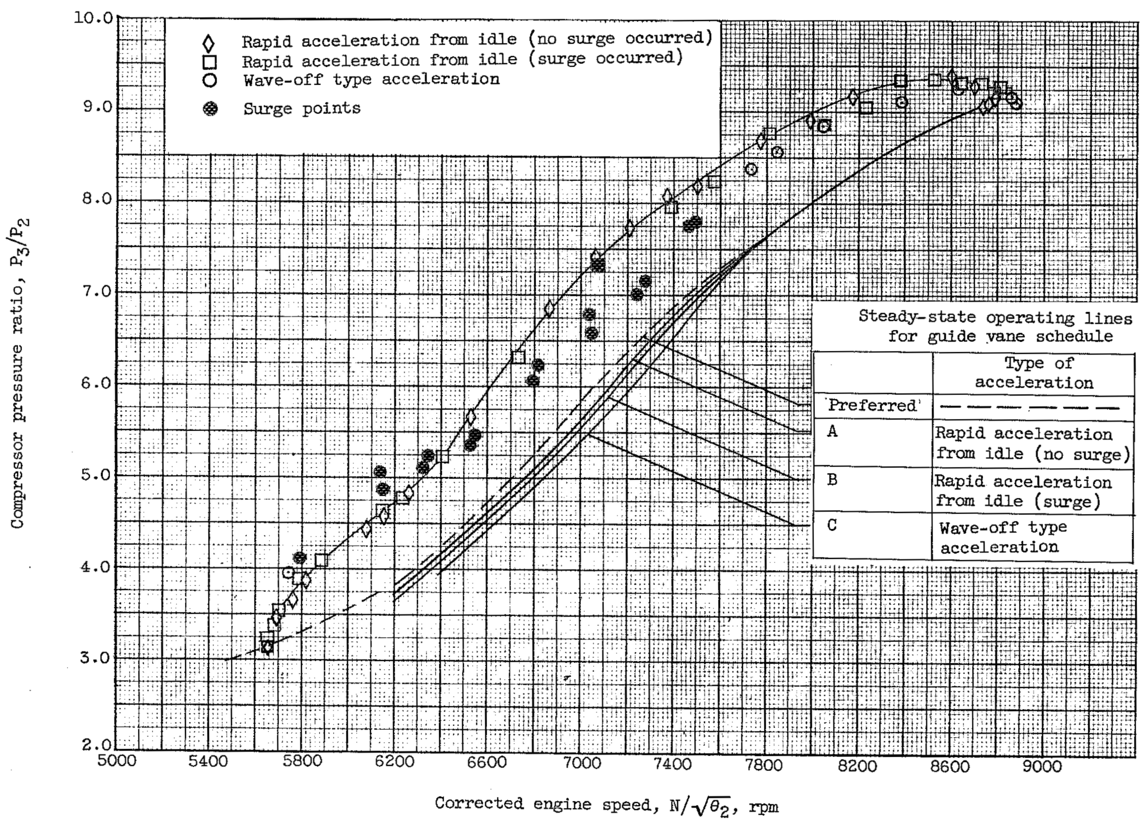
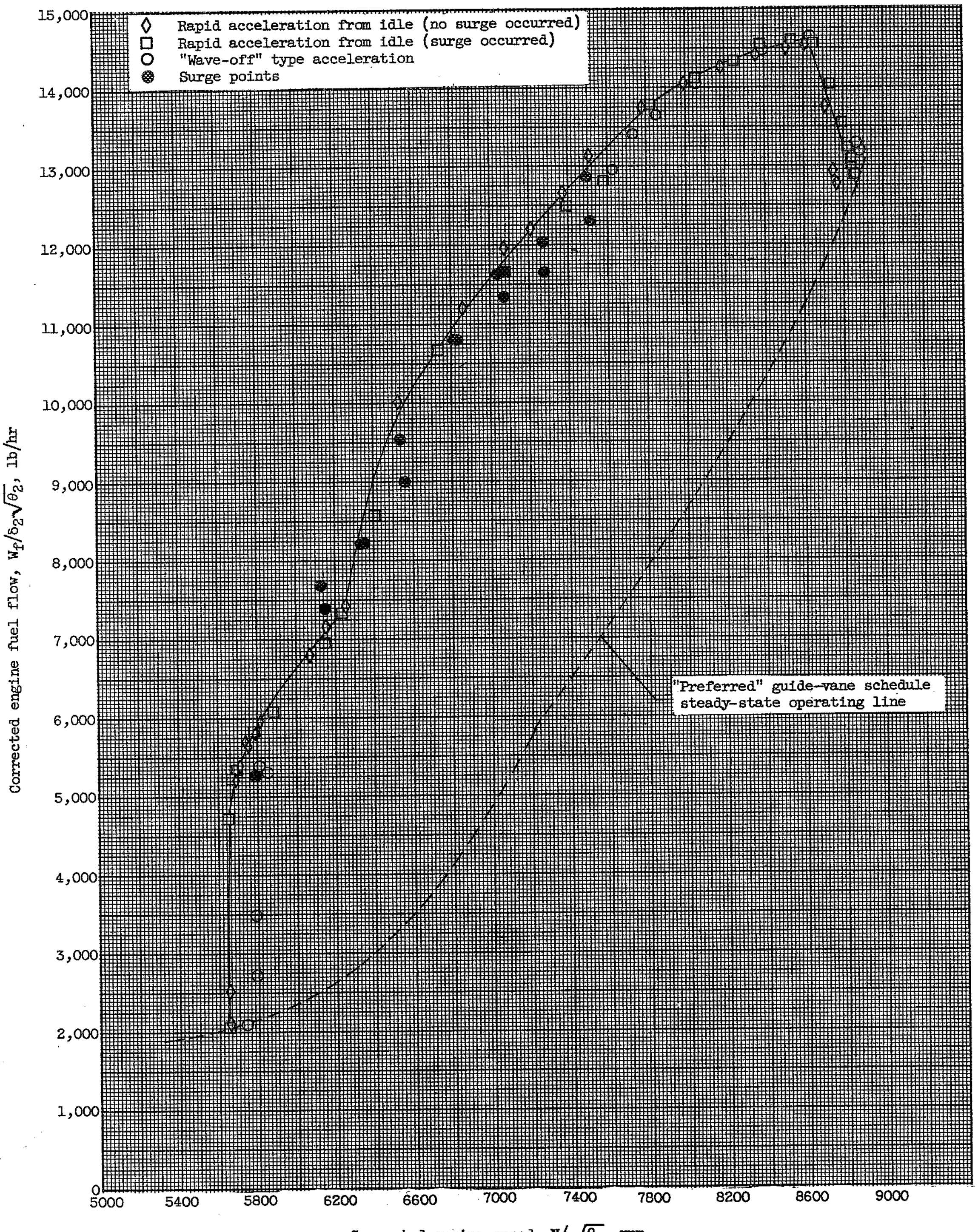


(a) Inlet-guide-vane position.



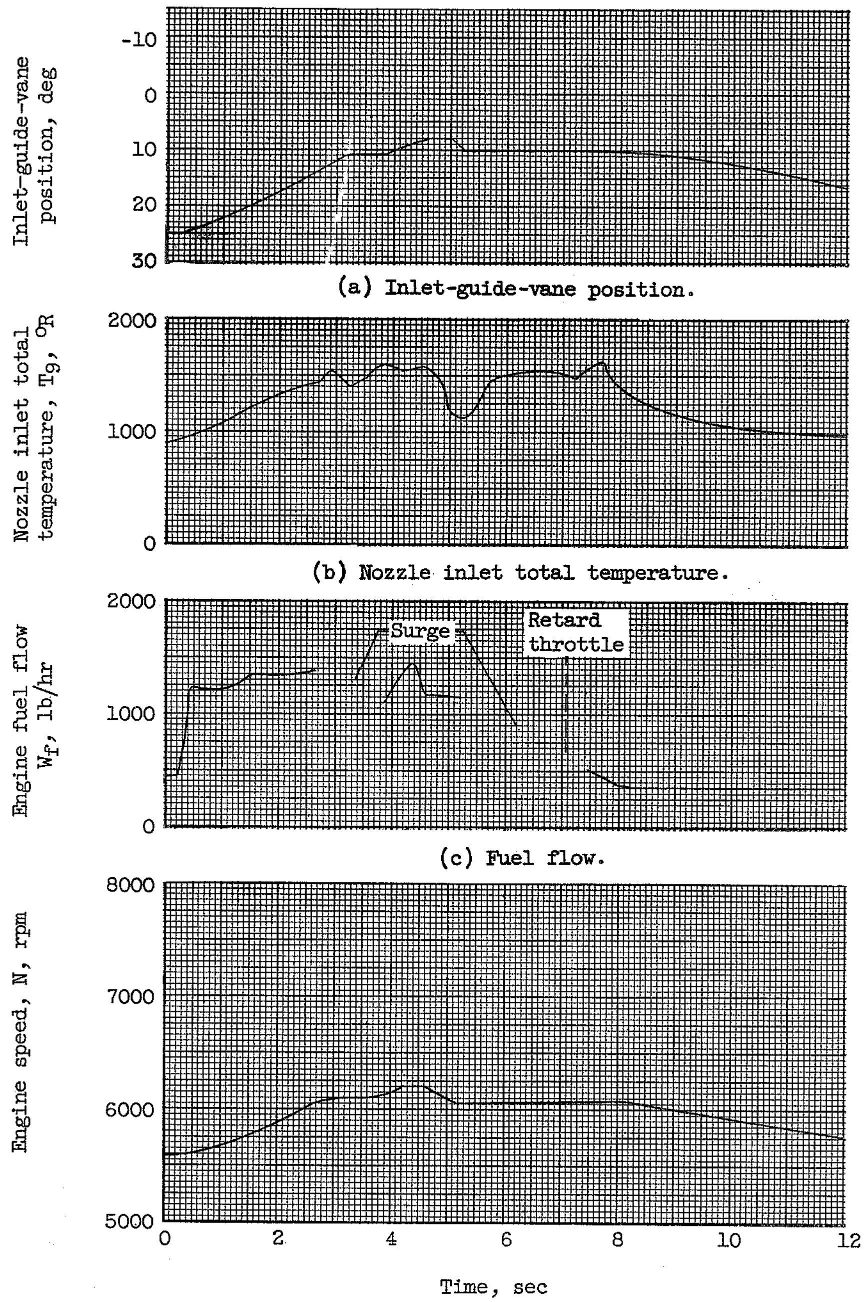
(b) Compressor pressure ratio.

Figure 9. - Acceleration path comparisons at 35,000 ft; flight Mach number, 0.4.



(c) Corrected engine fuel flow.

Figure 9. - Concluded. Acceleration path comparisons at 35,000 ft; flight Mach number, 0.4.



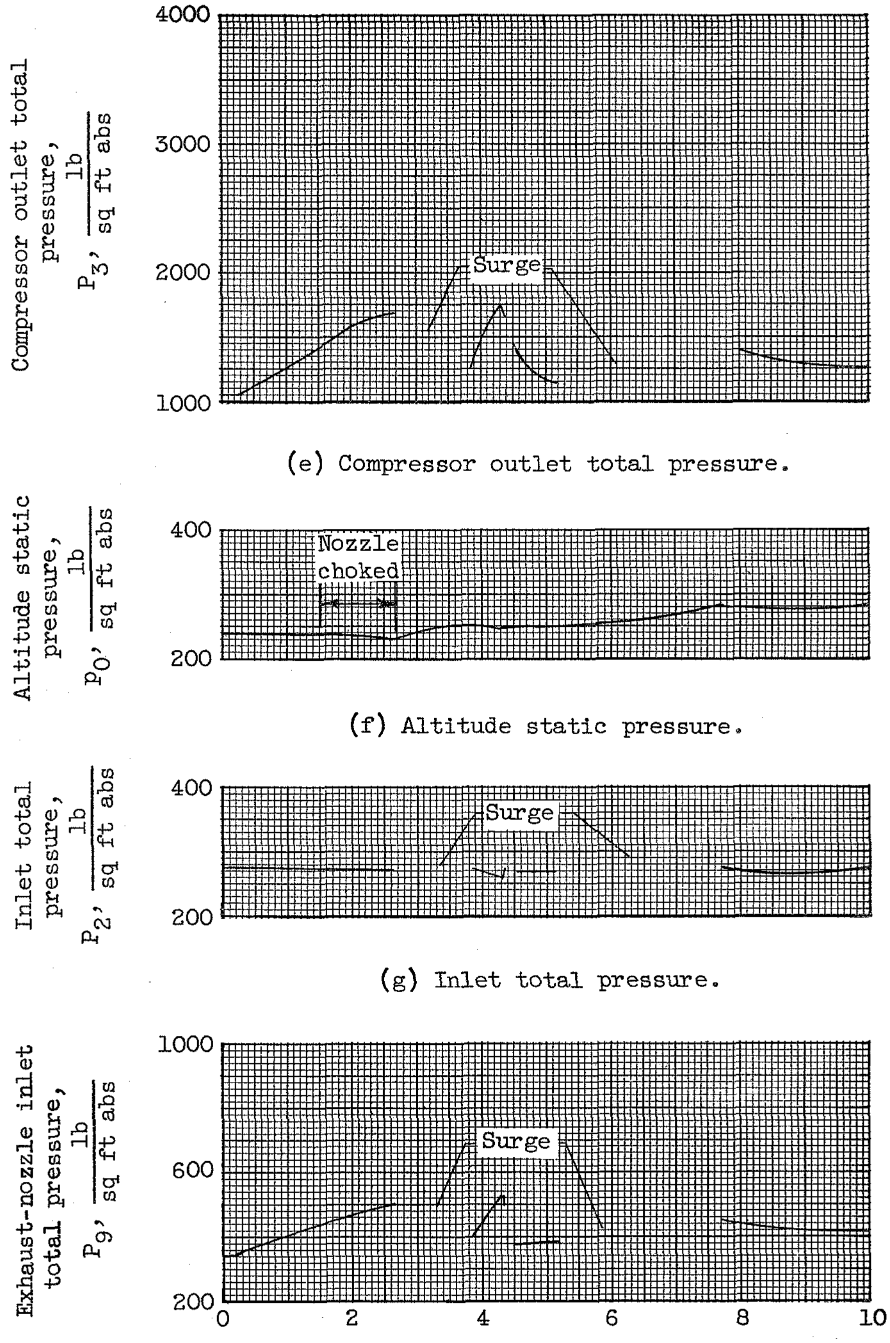
(a) Inlet-guide-vane position.

(b) Nozzle inlet total temperature.

(c) Fuel flow.

(d) Engine speed. Compressor inlet temperature, 414° R.

Figure 10. - Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.



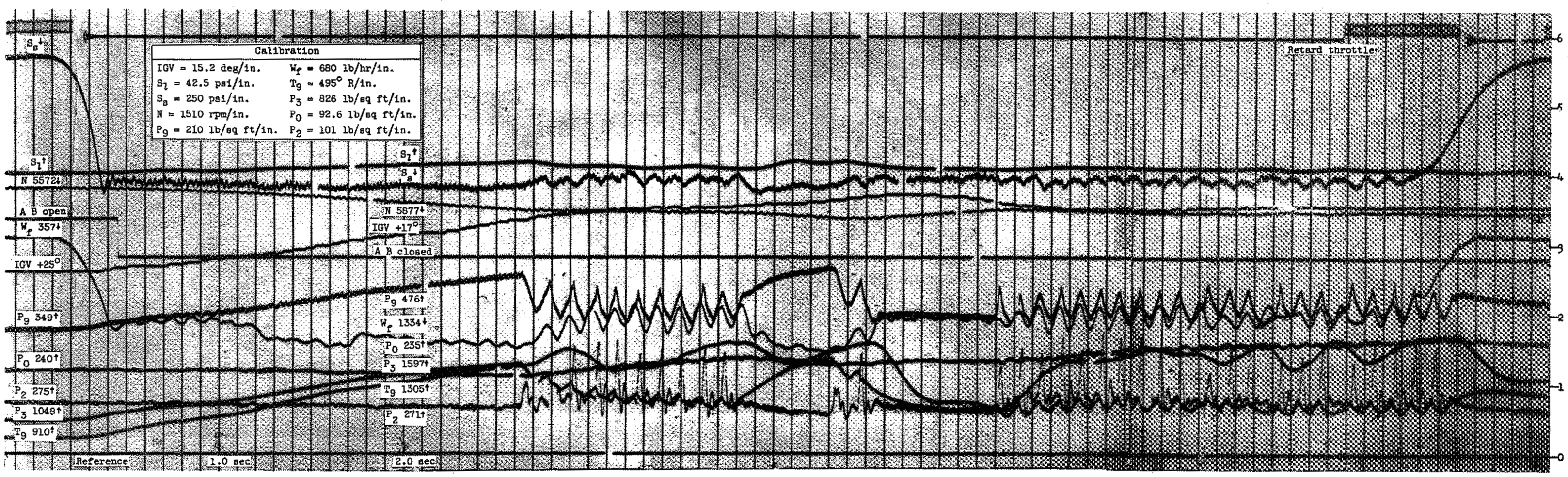
(e) Compressor outlet total pressure.

(f) Altitude static pressure.

(g) Inlet total pressure.

(h) Exhaust-nozzle inlet total pressure.

Figure 10. - Continued. Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.



(i) Reproduction of oscillograph traces.

Figure 10. - Concluded. Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.

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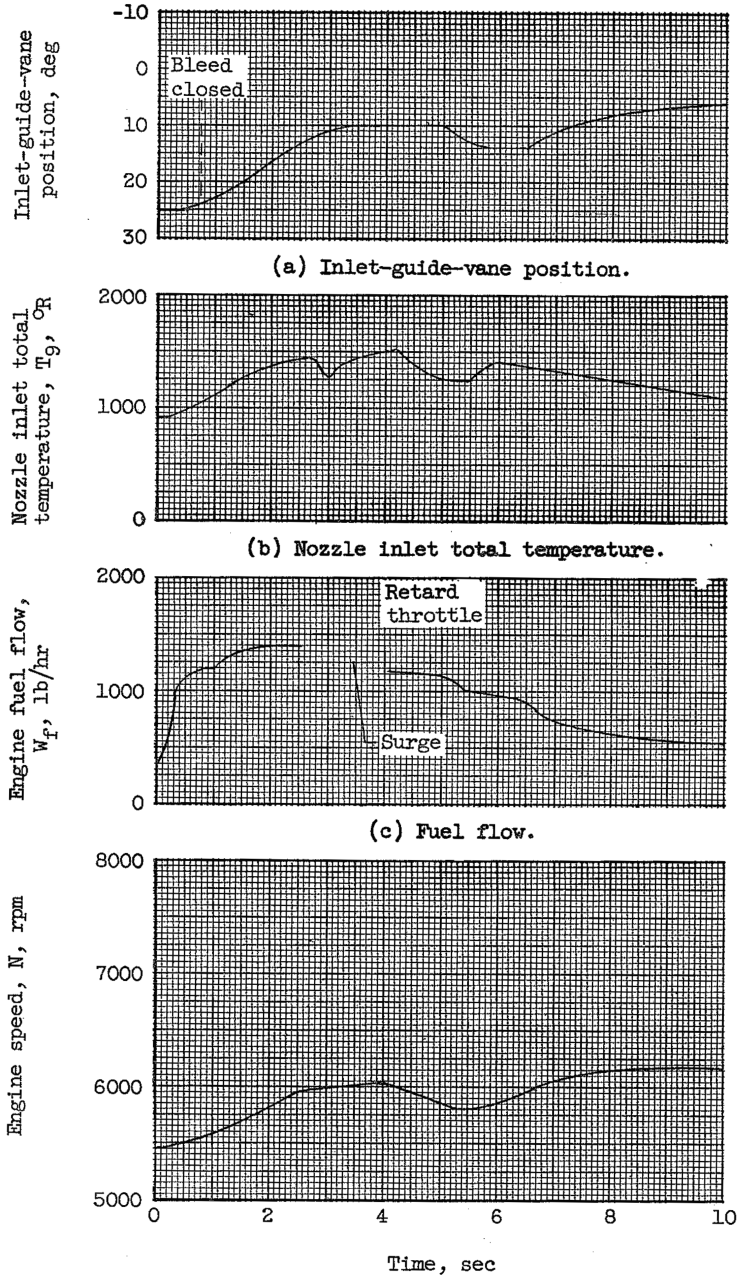
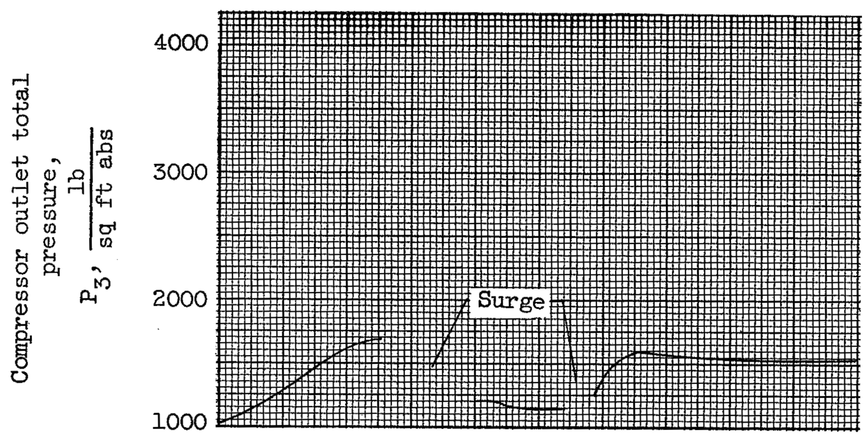
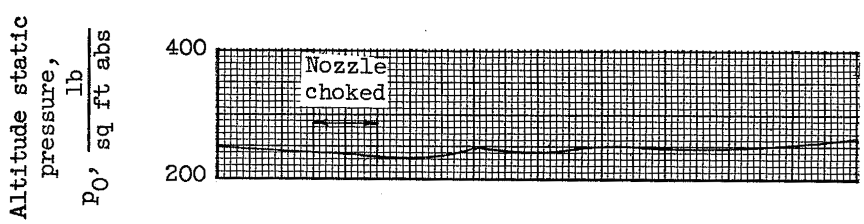


(d) Engine speed. Compressor inlet temperature, 414° R.

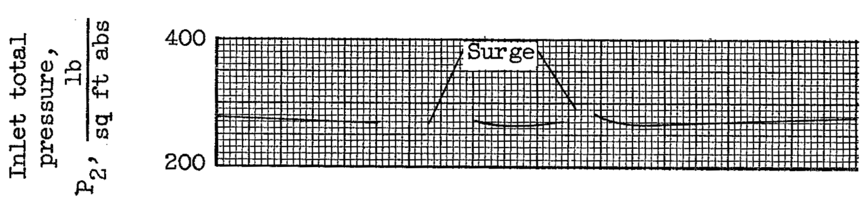
Figure 11. - Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.



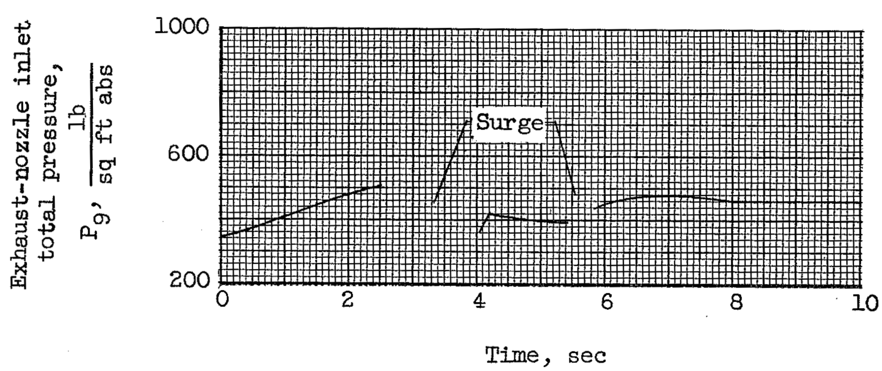
(e) Compressor outlet total pressure.



(f) Altitude static pressure.

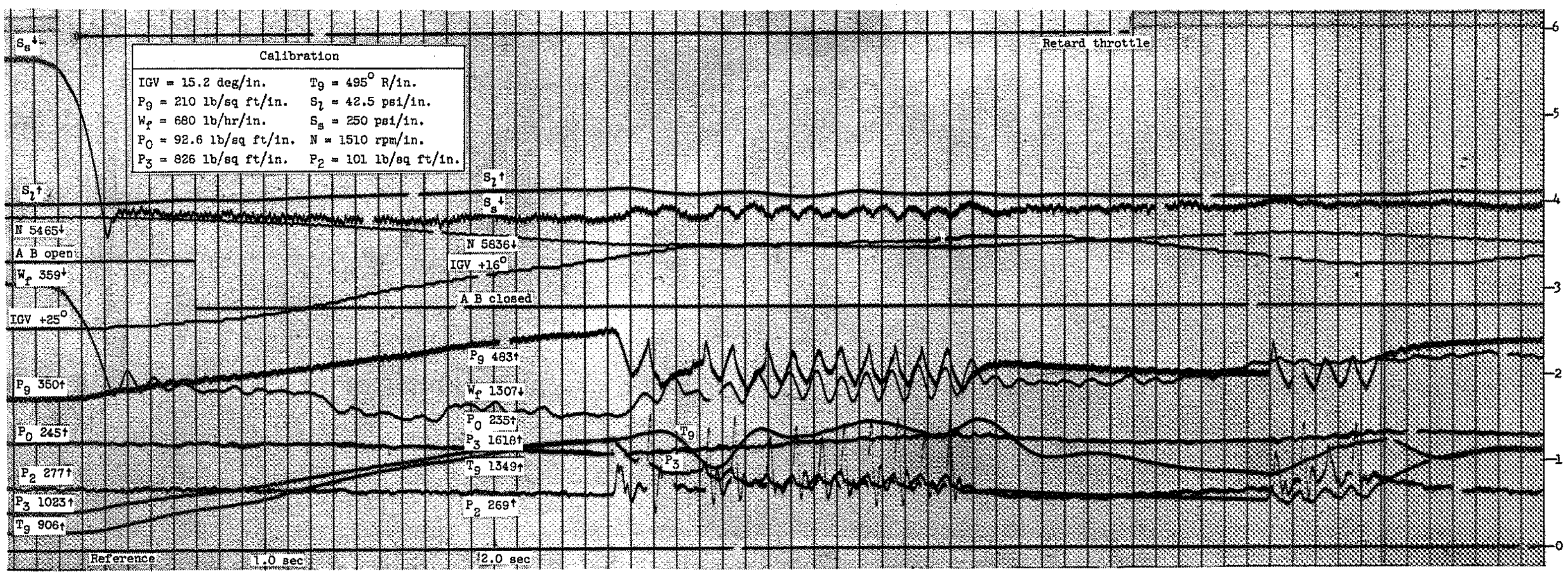


(g) Inlet total pressure.



(h) Exhaust-nozzle inlet total pressure.

Figure 11. - Continued. Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.



(i) Reproduction of oscillograph traces.

Figure 11. - Concluded. Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.

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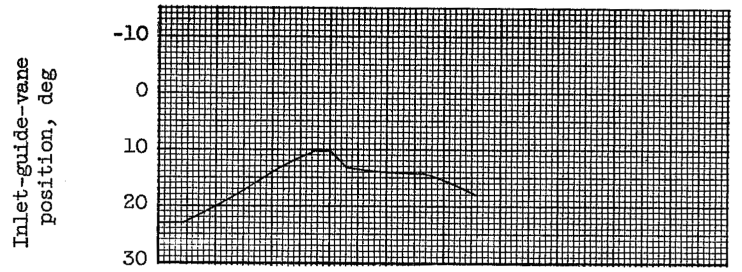
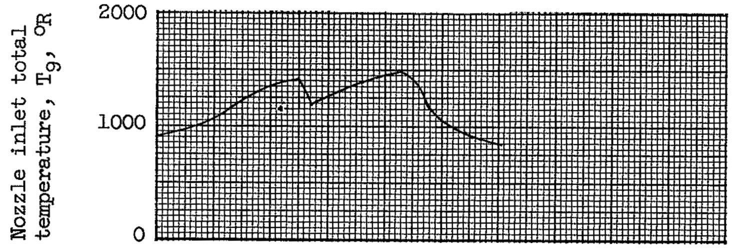
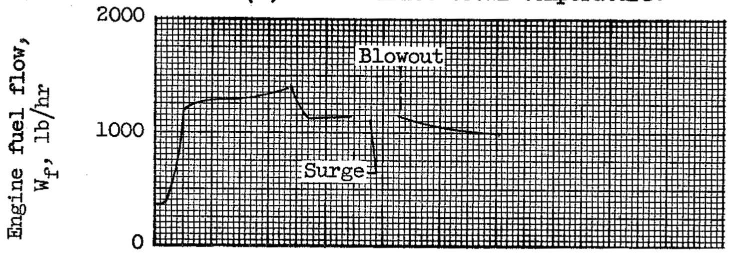


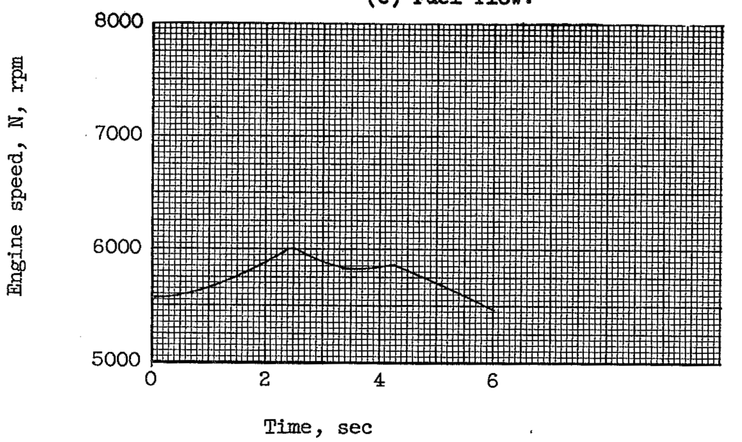
(a) Inlet-guide-vane position.



(b) Nozzle inlet total temperature.

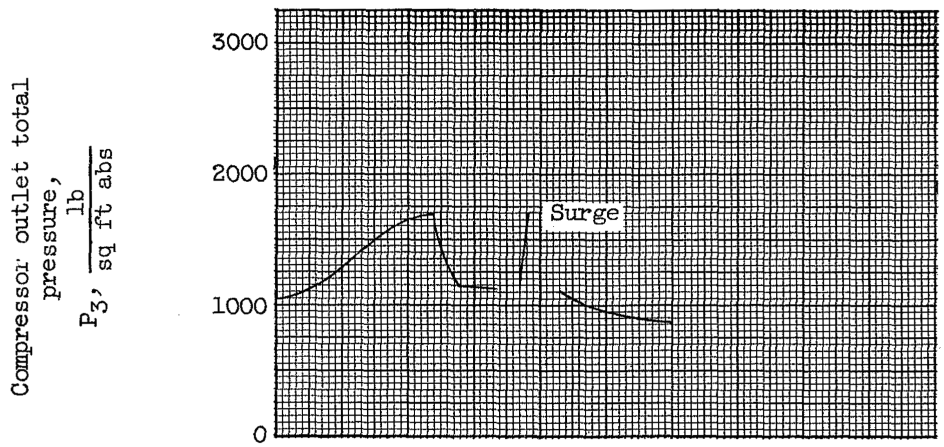


(c) Fuel flow.

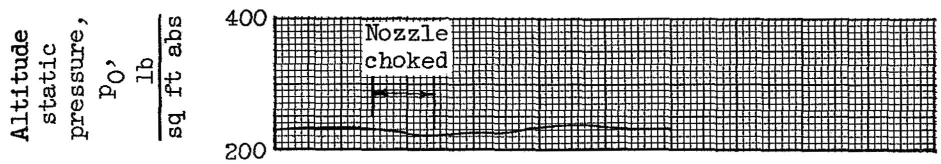


(d) Engine speed. Compressor inlet temperature, 414° R.

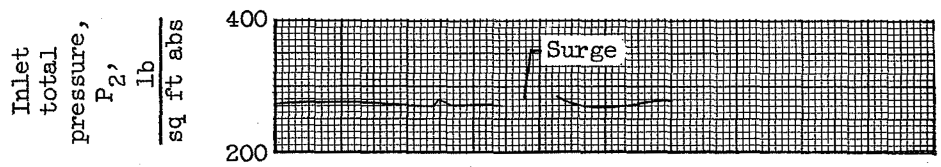
Figure 12. - Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. **Surge and blowout occurred.**



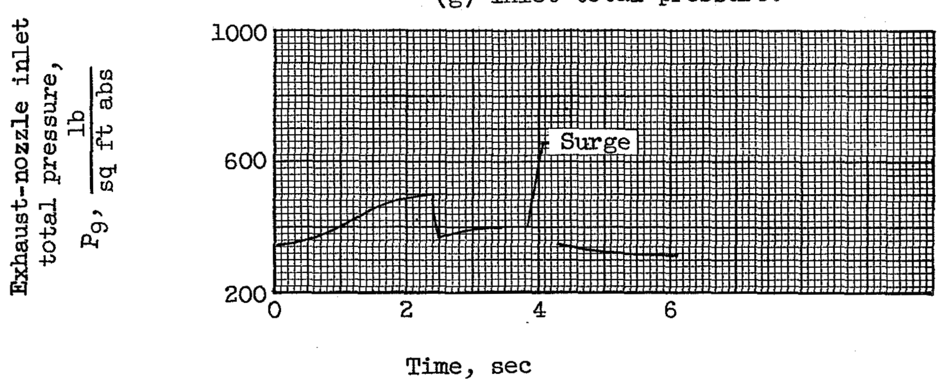
(e) Compressor outlet total pressure.



(f) Altitude static pressure.

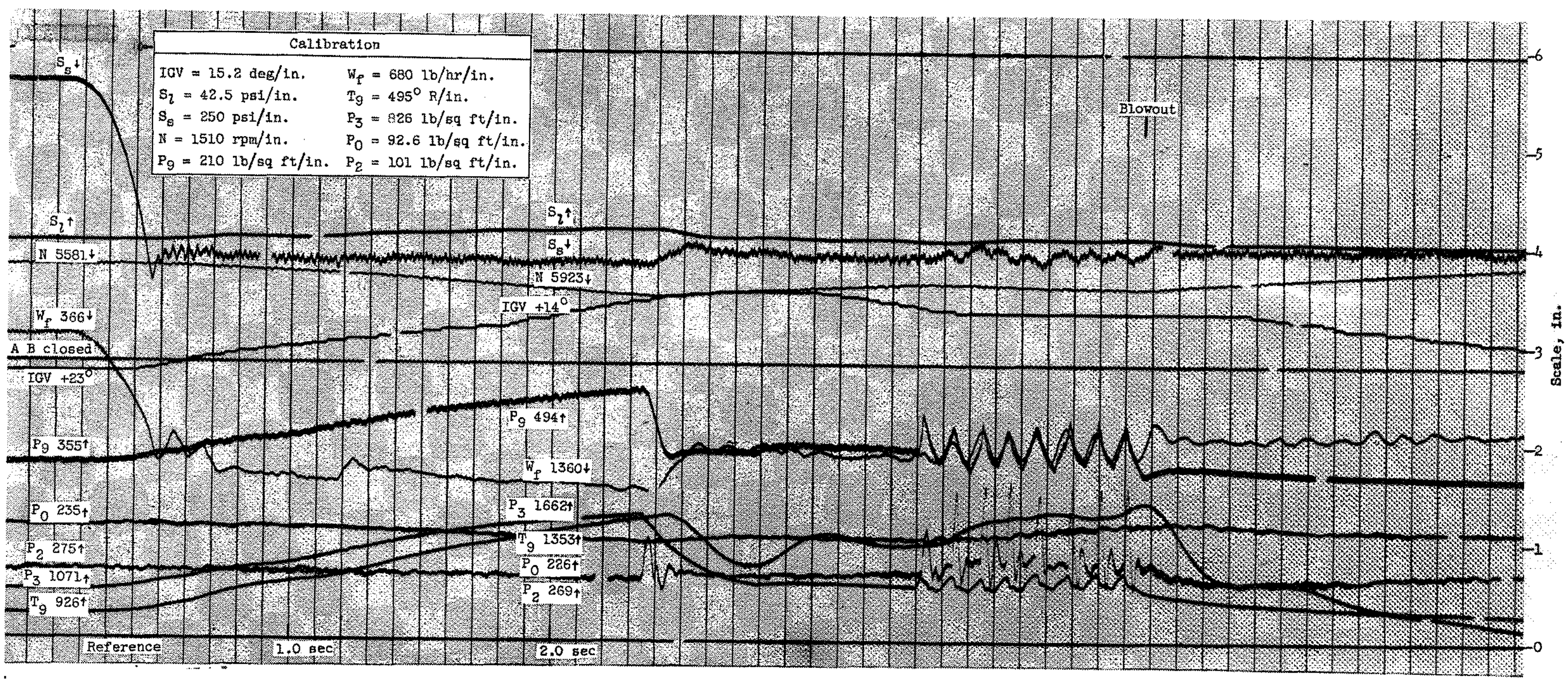


(g) Inlet total pressure.



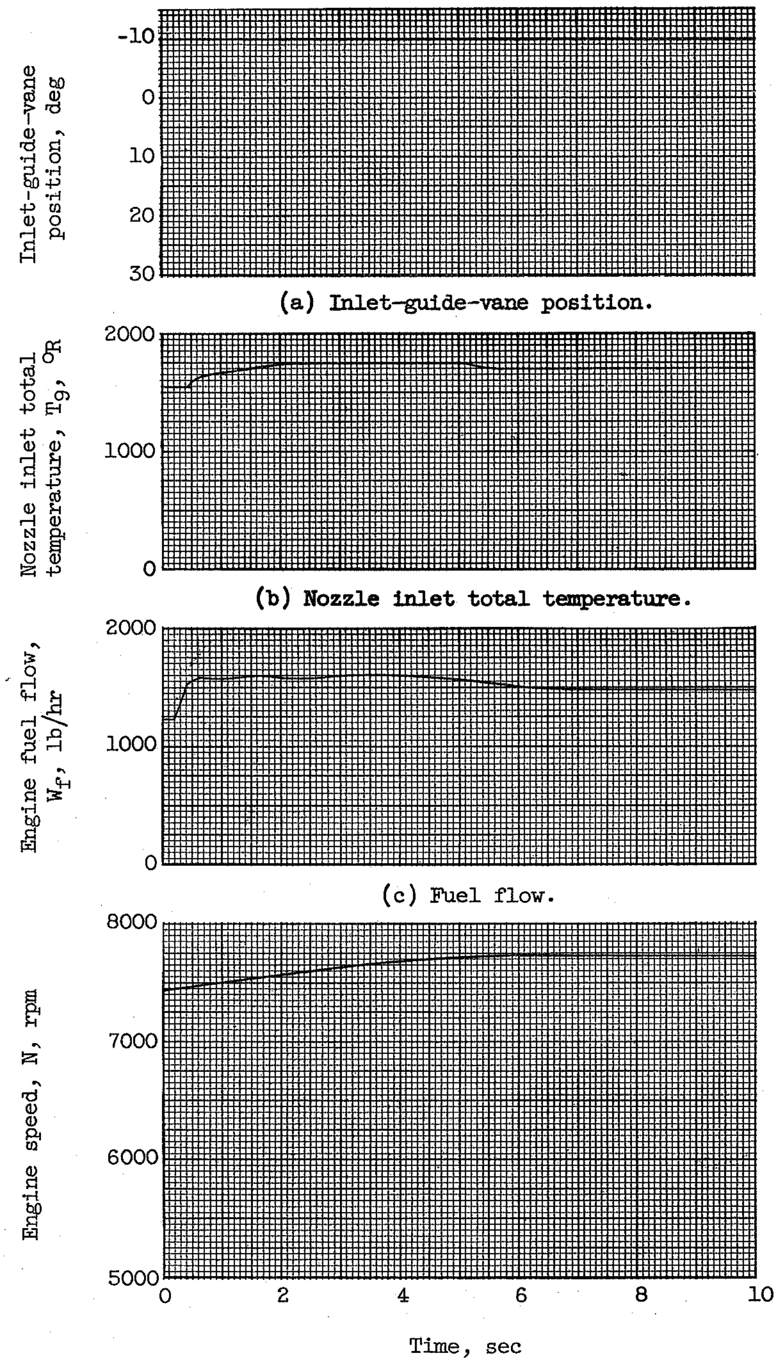
(h) Exhaust-nozzle inlet total pressure.

Figure 12. - Continued. Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



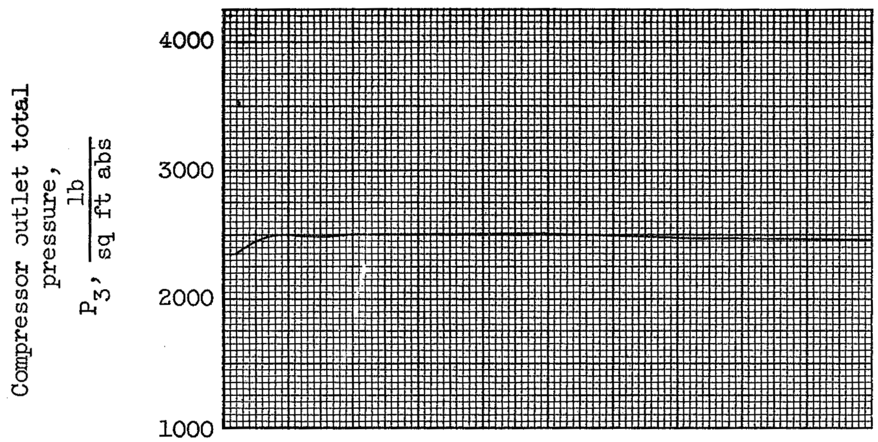
(i) Reproduction of oscillograph traces.

Figure 12. - Concluded. Acceleration attempt from idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.

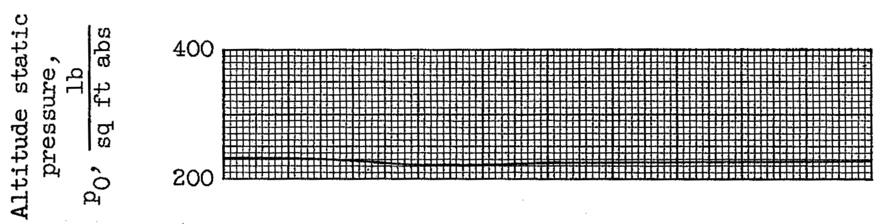


(d) Engine speed. Compressor inlet temperature, 411° R.

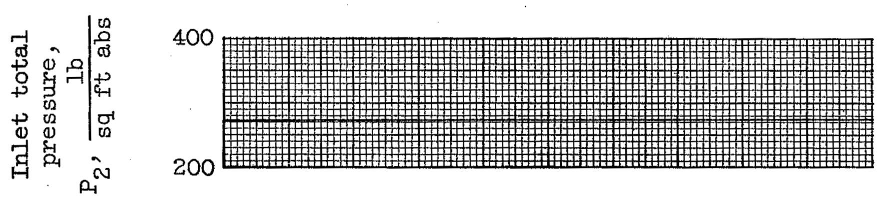
Figure 13. - Acceleration attempt from 7450 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. No surge occurred.



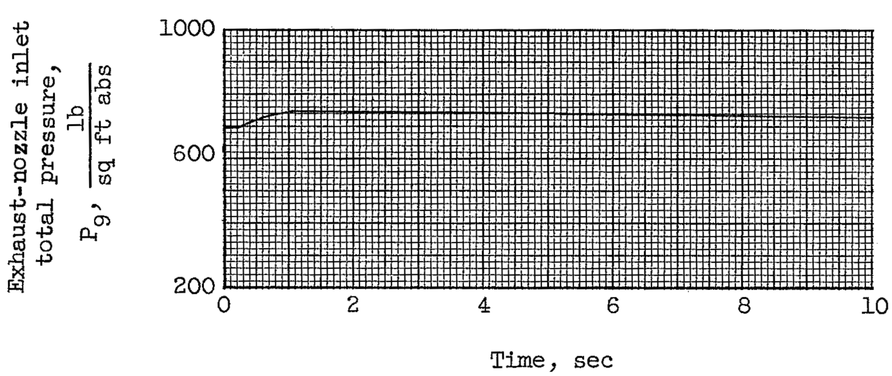
(e) Compressor outlet total pressure.



(f) Altitude static pressure.

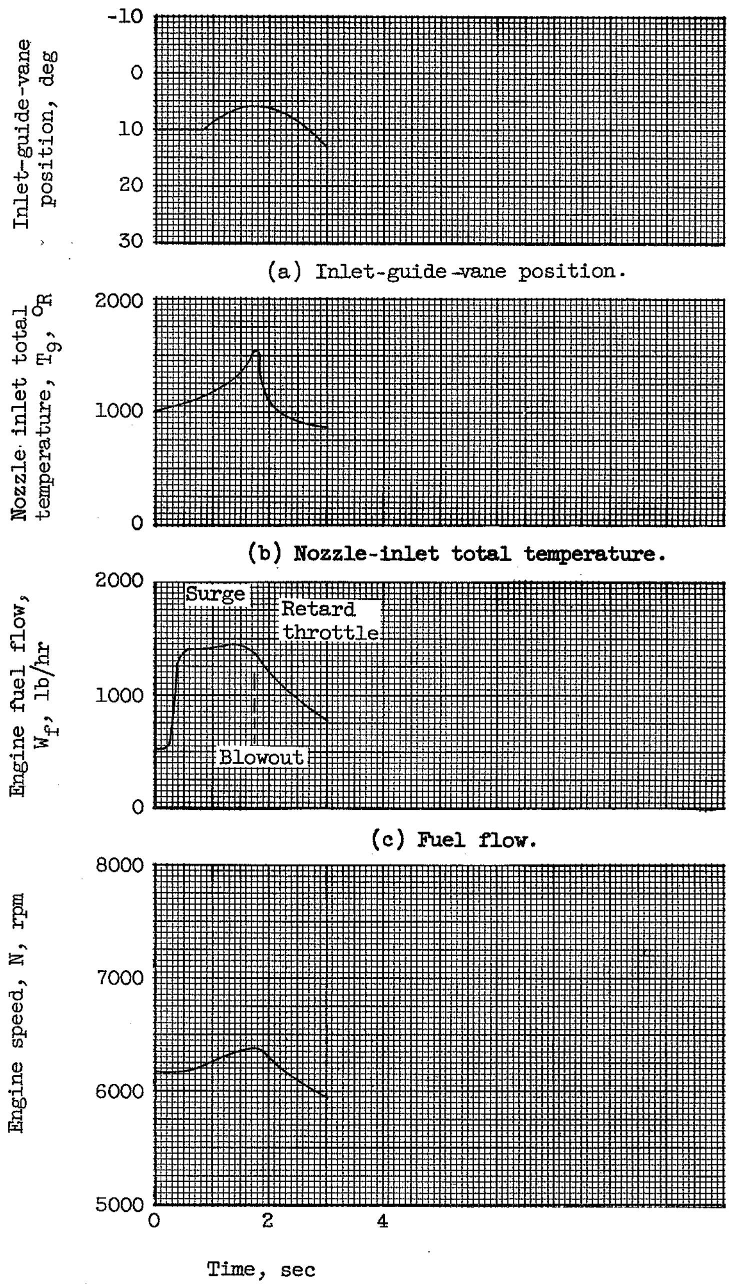


(g) Inlet total pressure.



(h) Exhaust-nozzle inlet total pressure.

Figure 13. - Concluded. Acceleration attempt from 7450 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. No surge occurred.



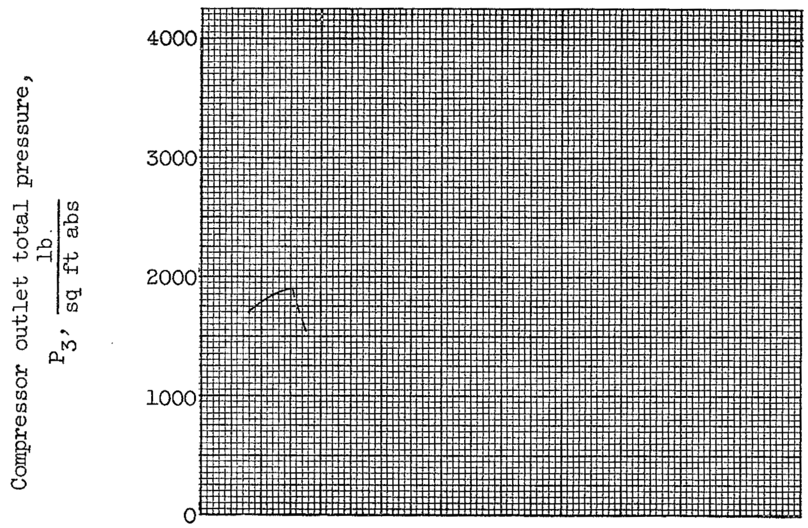
(a) Inlet-guide-vane position.

(b) Nozzle-inlet total temperature.

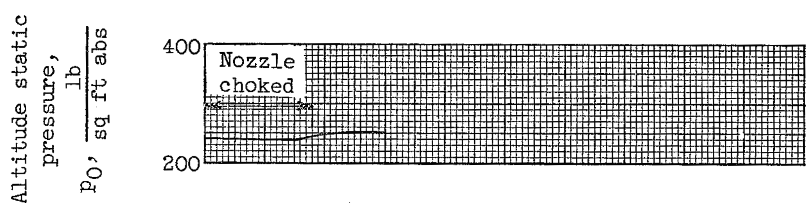
(c) Fuel flow.

(d) Engine speed. Compressor inlet temperature, 411° R.

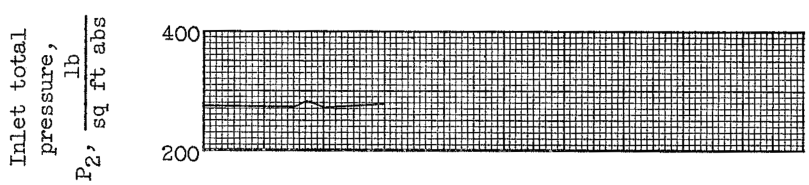
Figure 14. - Acceleration attempt from 6150 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



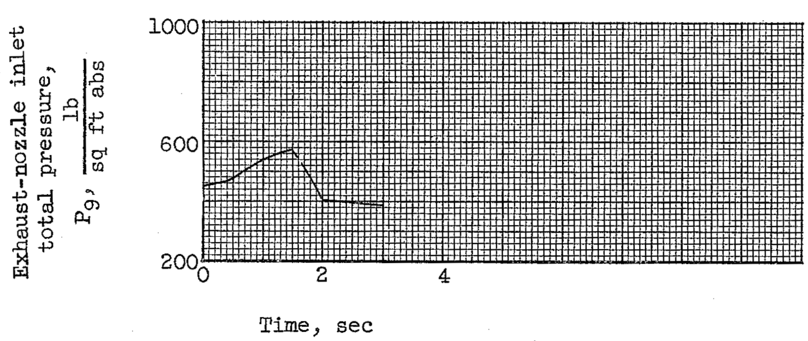
(e) Compressor outlet total pressure.



(f) Altitude static pressure.

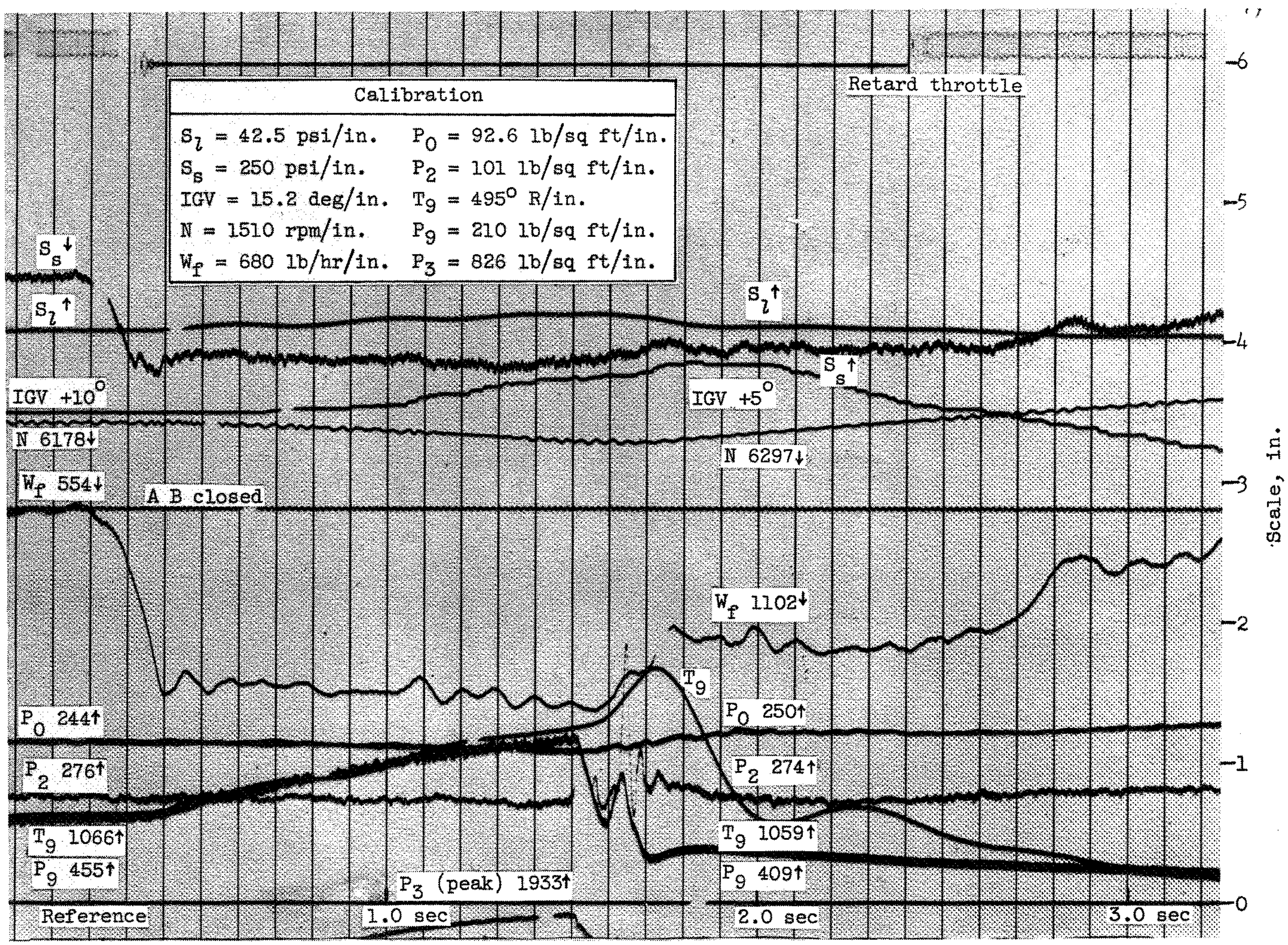


(g) Inlet total pressure.



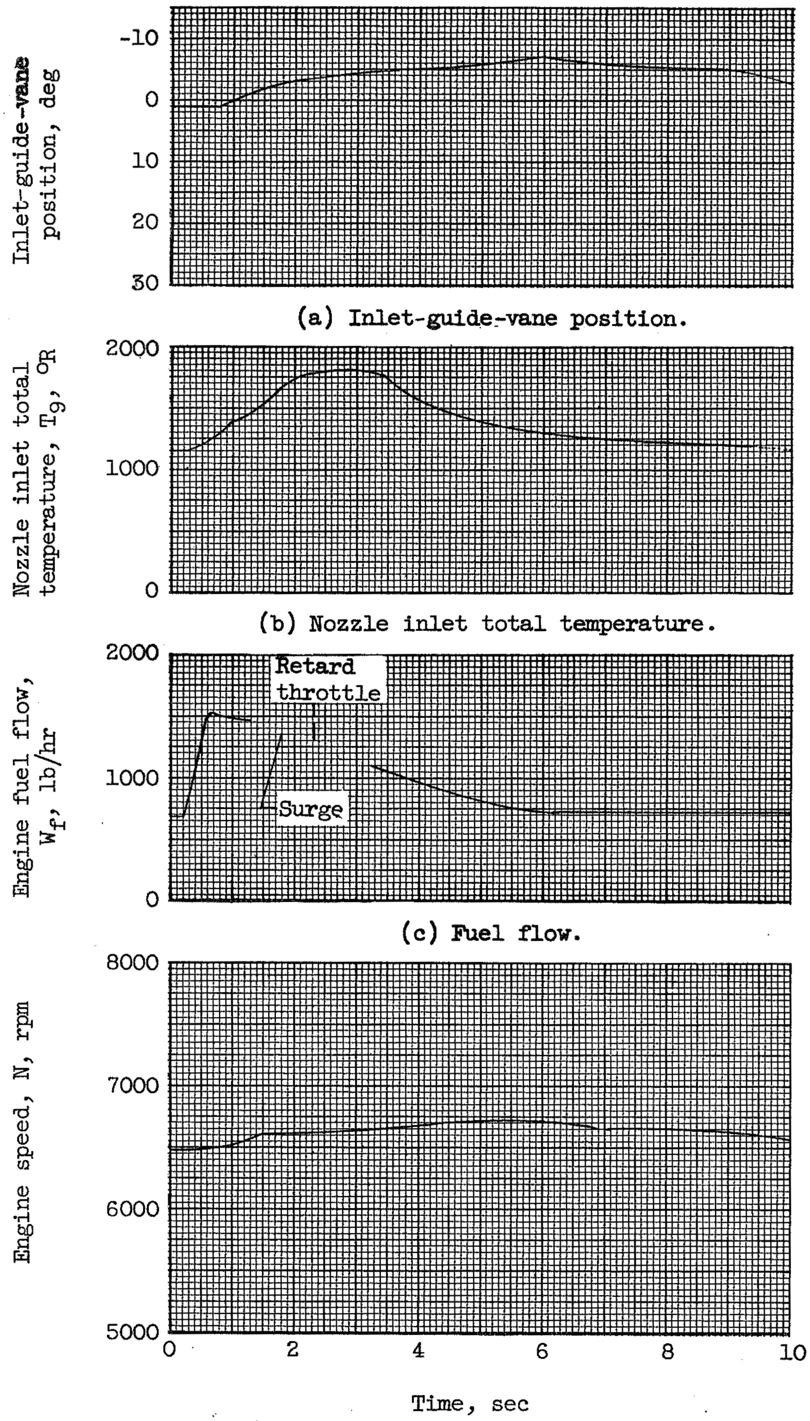
(h) Exhaust-nozzle inlet total pressure.

Figure 14. - Continued. Acceleration attempt from 6150 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



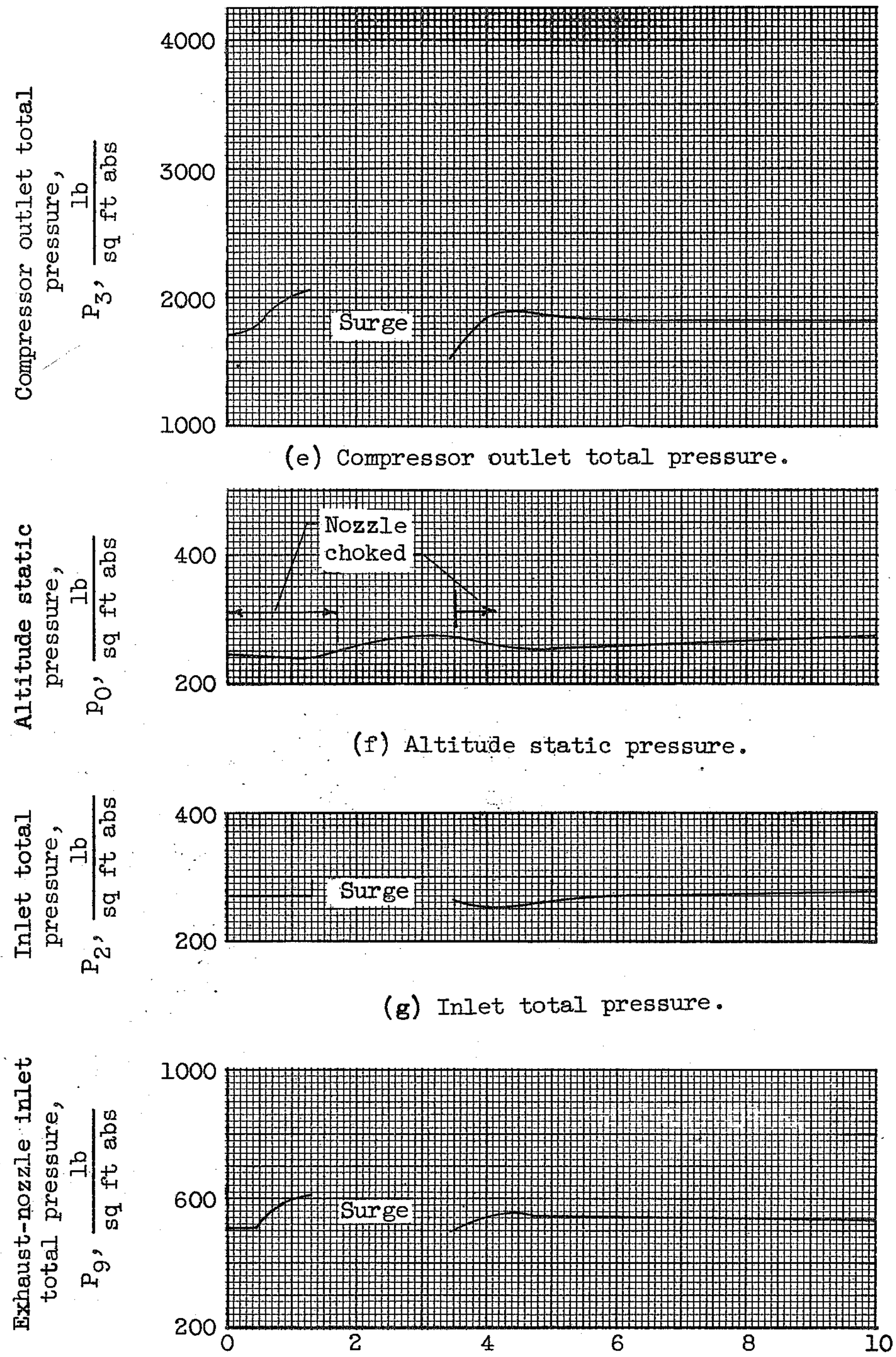
(i) Reproduction of oscillograph traces.

Figure 14. - Concluded. Acceleration attempt from 6150 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



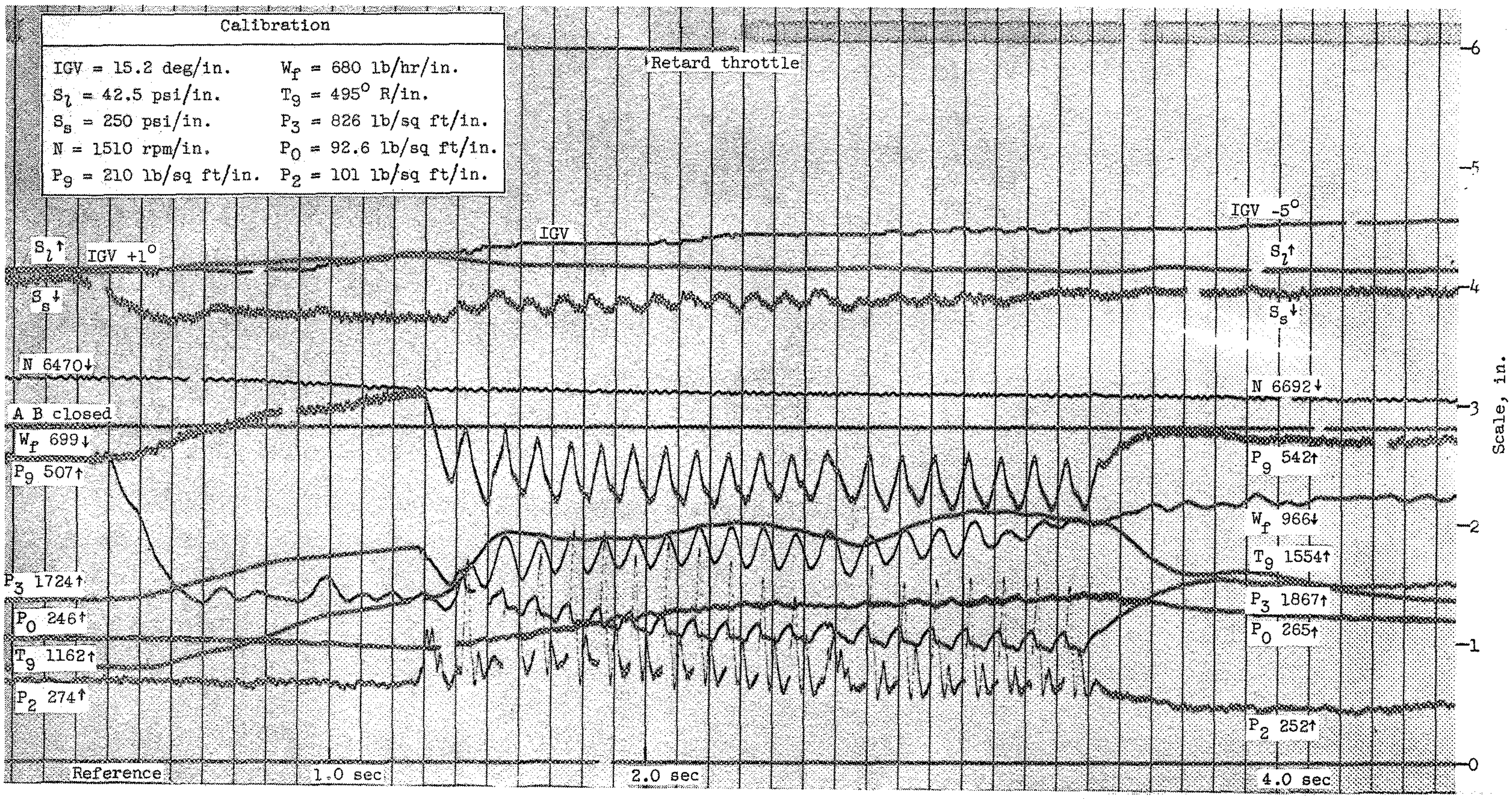
(d) Engine speed. Compressor inlet temperature, 412° R.

Figure 15. - Acceleration attempt from 6430 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.



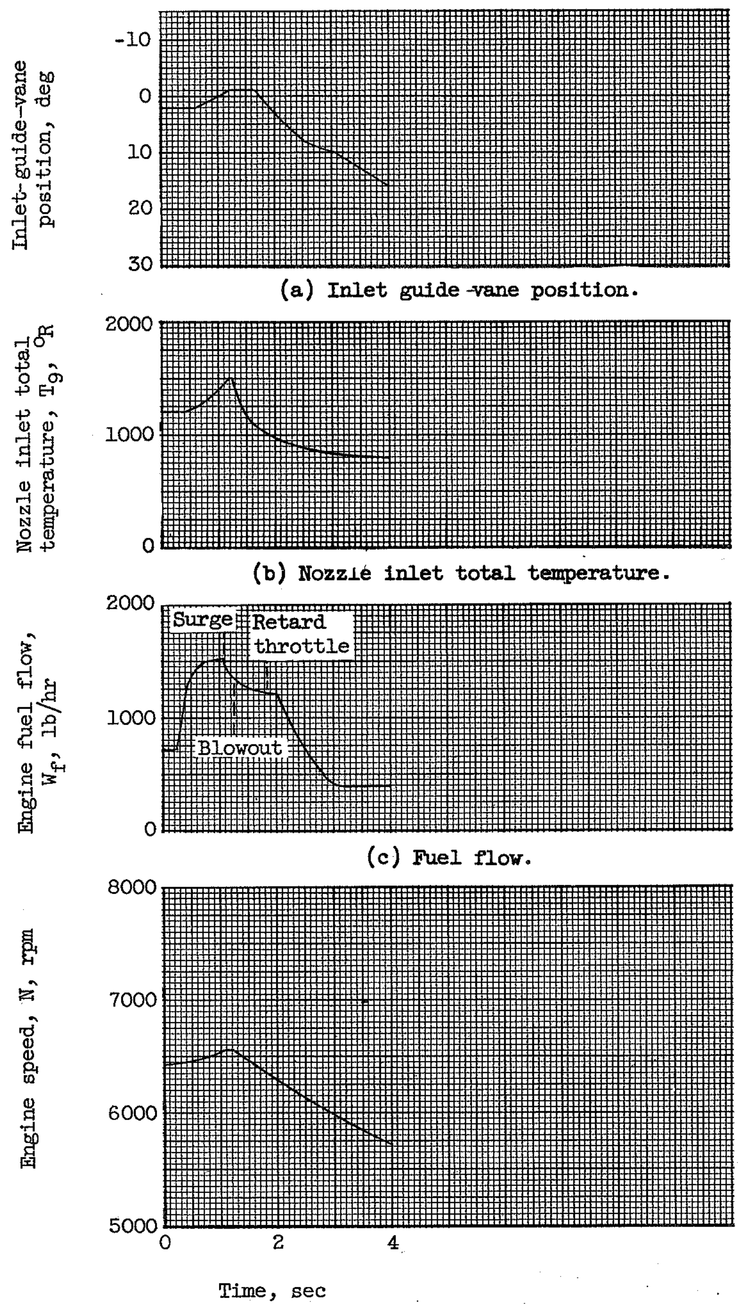
(h) Exhaust-nozzle inlet total pressure.

Figure 15. - Continued. Acceleration attempt from 6430 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.



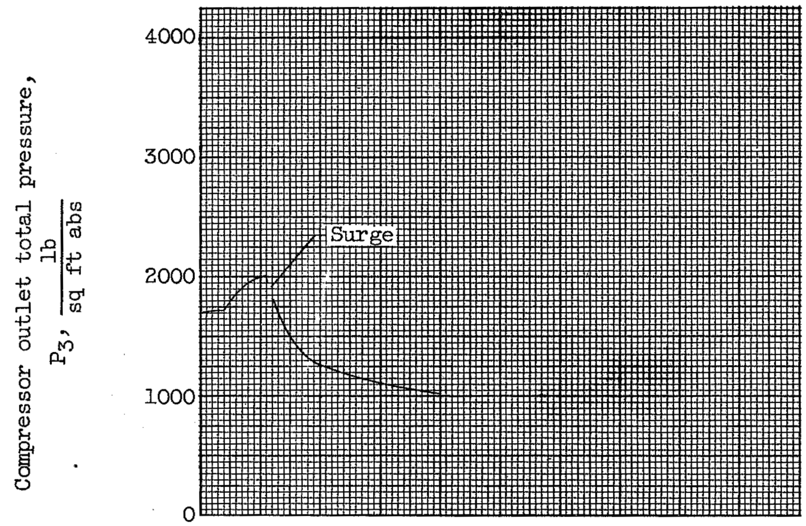
(i) Reproduction of oscillograph traces.

Figure 15. - Concluded. Acceleration attempt from 6430 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred.

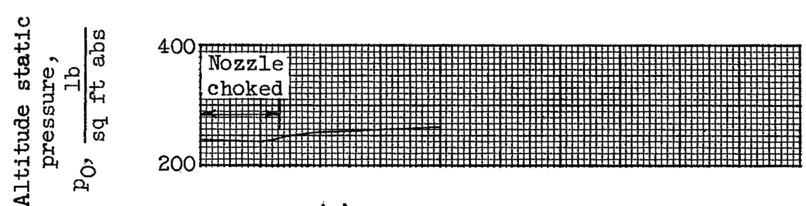


(d) Engine speed. Compressor inlet temperature, 412° R.

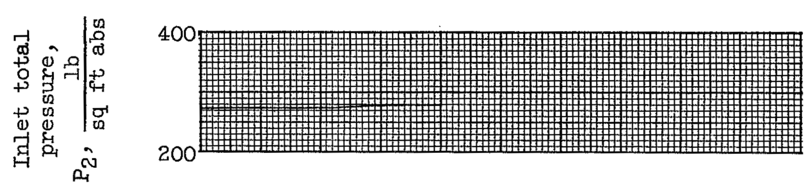
Figure 16. - Acceleration attempt from 6430 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



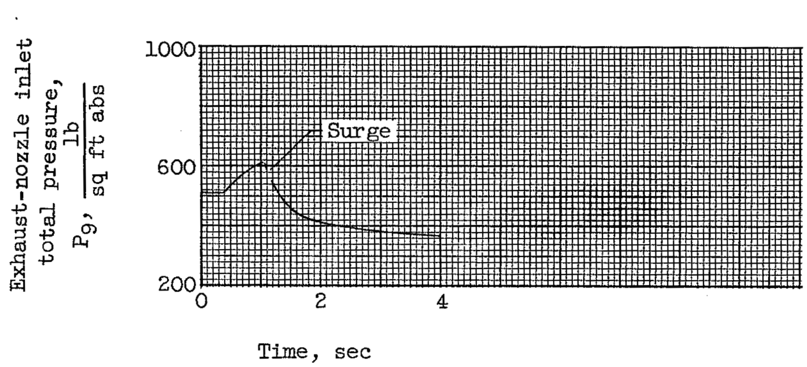
(e) Compressor outlet total pressure.



(f) Altitude static pressure.

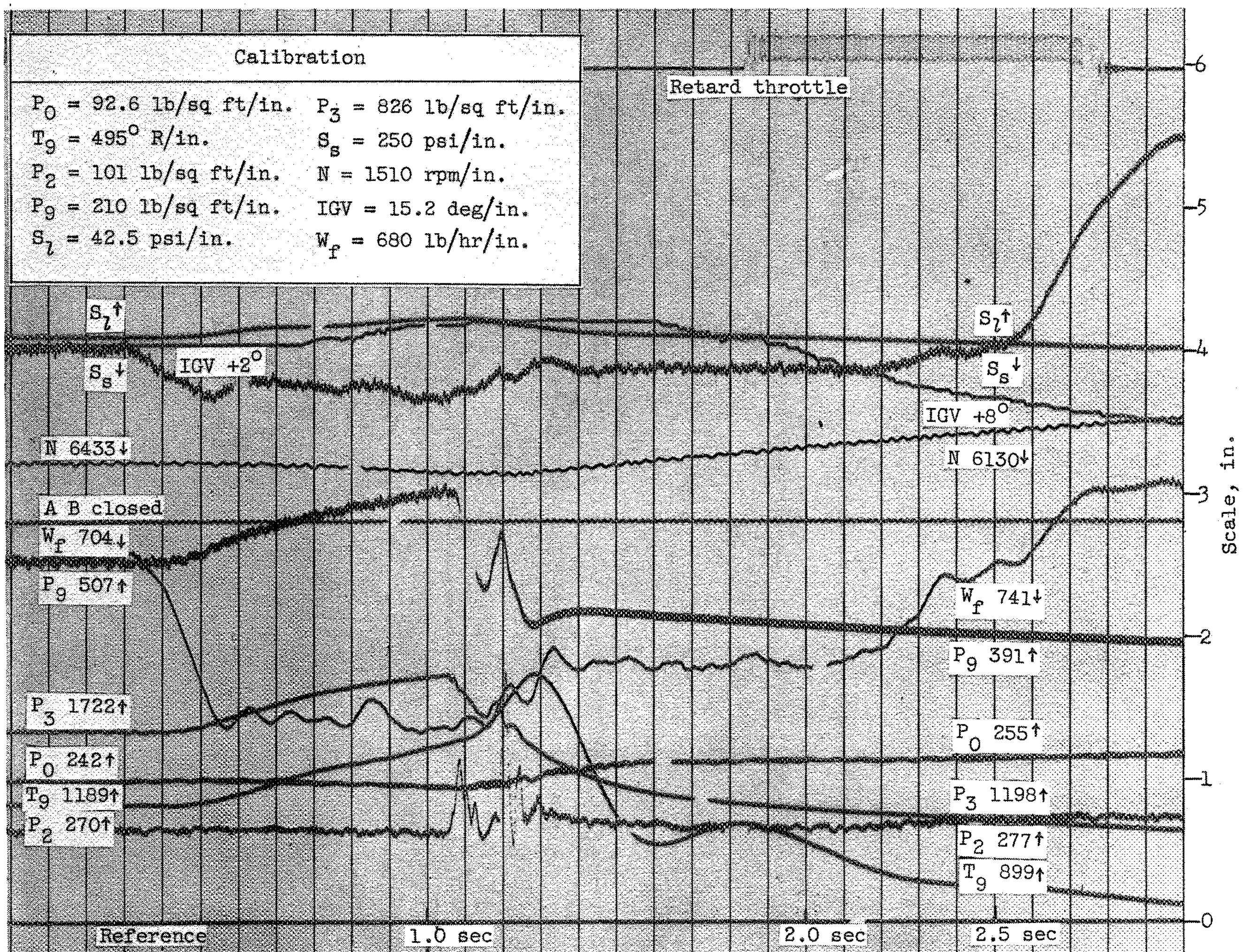


(g) Inlet total pressure.



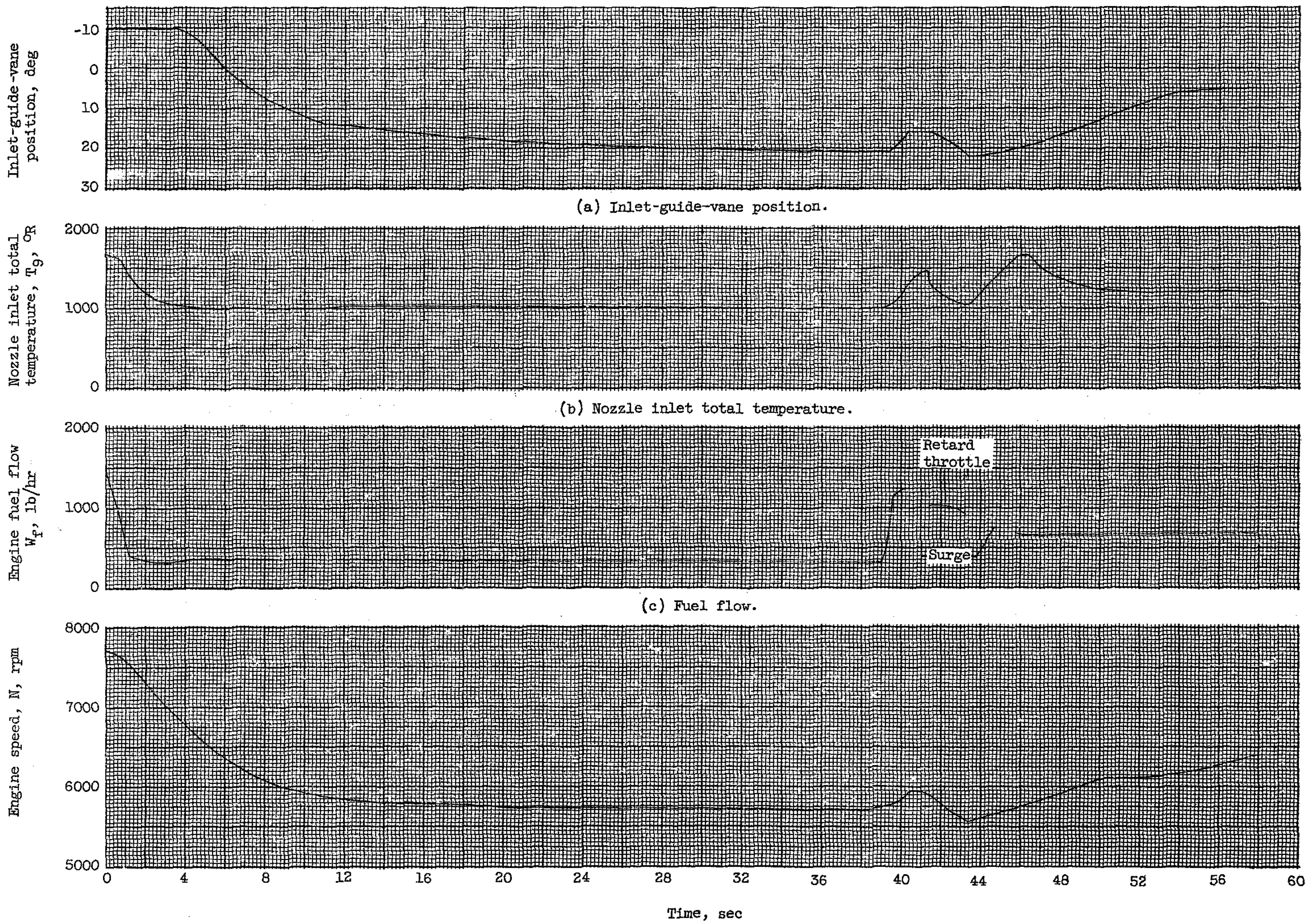
(h) Exhaust-nozzle inlet total pressure.

Figure 16. - Continued. Acceleration attempt from 6430 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



(i) Reproduction of oscillograph traces.

Figure 16. - Concluded. Acceleration attempt from 6430 rpm to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge and blowout occurred.



(a) Inlet-guide-vane position.

(b) Nozzle inlet total temperature.

(c) Fuel flow.

(d) Engine speed. Compressor inlet temperature, 411° R.

Figure 17. - Wave-off type acceleration from rated speed to idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4 Surge occurred during acceleration.

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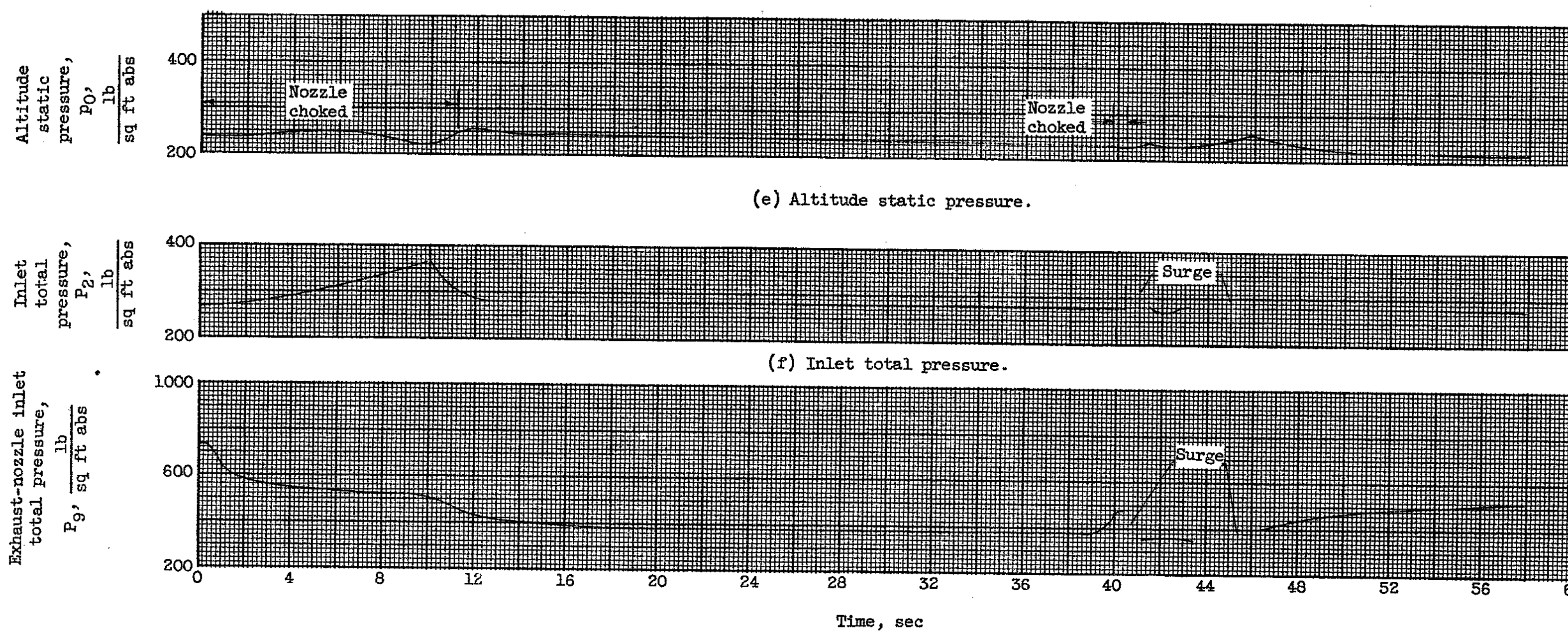

(g) Exhaust-nozzle inlet total pressure.

Figure 17. - Continued. Wave-off type acceleration from rated speed to idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred during acceleration.

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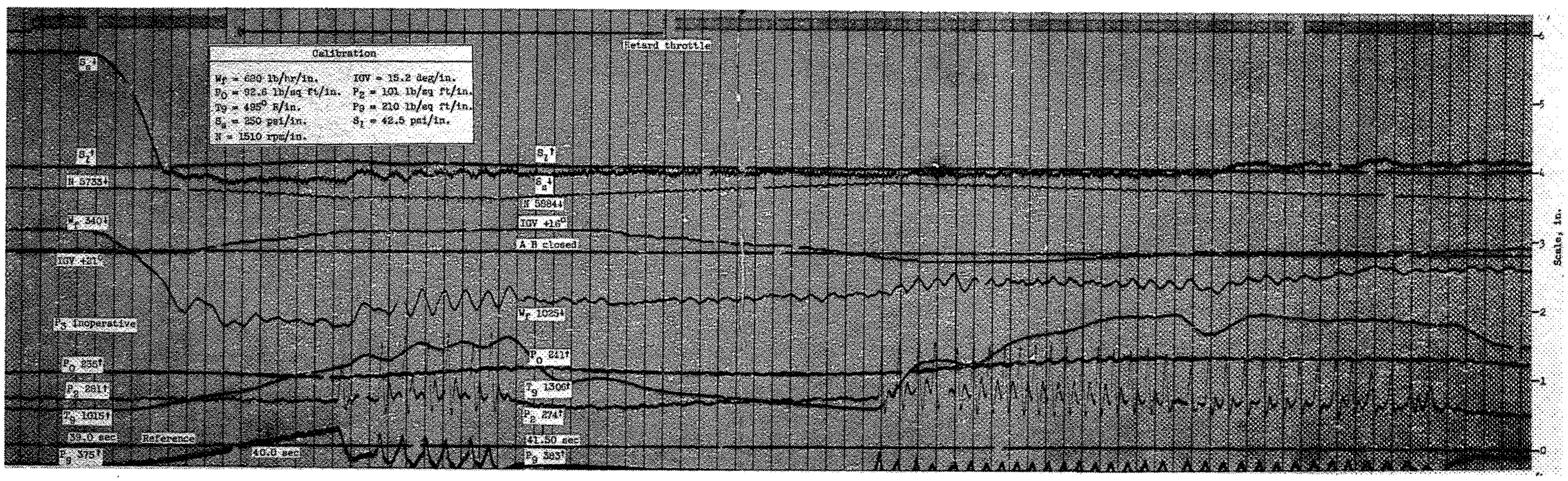

(h) Reproduction of oscillograph traces.

Figure 17. - Concluded. Wave-off type acceleration from rated speed to idle to rated speed. Altitude, 50,000 feet; flight Mach number, 0.4. Surge occurred during acceleration.

ALTITUDE ACCELERATION INVESTIGATION OF THE

RA-14 AVON TURBOJET ENGINE

4023

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cjk - 3/13/56

Engines, Turbojet 3.1.3

Engines, Control - Turbojet 3.2.2

Compressors - Axial Flow 3.6.1.1

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ALTITUDE ACCELERATION INVESTIGATION OF THE

RA-14 AVON TURBOJET ENGINE

Abstract

As a part of this investigation, the acceleration characteristics of the engine, using the standard engine fuel-control system, were obtained for conditions simulating flight at altitudes of 35,000 and 50,000 feet with a flight Mach number of 0.4. Rapid and wave-off type accelerations were made at each flight condition, and the transient performance of the engine was recorded with a multiple-channel oscillograph. The parameters are presented graphically in the form of time histories, augmented by short segments of the oscillograph recordings, in order to more completely describe the behavior of the engine parameters when surge was encountered.